BULLETIN No. 58.

U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF CHEMISTRY.

THE MANUFACTURE OF STARCH FROM POTATOES AND CASSAVA.

BY HARVEY W. WILEY,

CHIEF OF THE DIVISION OF CHEMISTRY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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POTATOES GROWN IN ARISTOOK COUNTY, ME.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Chemistry,
Washington, D. C., April 19, 1900.

Sir: I have the honor to transmit to you herewith the manuscript of a bulletin describing my observations in the manufacture of starch from potatoes in Maine, together with descriptions of machinery and processes for the manufacture of starch from potatoes and cassava. There are also included in this bulletin data relating to the industry of starch manufacture from potatoes in other parts of the country.

I recommend that this be printed as Bulletin No. 58 of the Division of Chemistry.

Respectfully,

H. W. Wiley,
Chief of the Division of Chemistry.

Hon. James Wilson,
Secretary of Agriculture.

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THE MANUFACTURE OF STARCH FROM POTATOES AND CASSAVA.

MAKING STARCH FROM POTATOES.

AMOUNT OF PRODUCT AND DESCRIPTION OF SOIL.

The total annual production of starch from potatoes in the United States is about 15,500 tons,[1] of which 6,000 tons are produced in the county of Aroostook, in Maine. The soil of this county presents a gently rolling surface, and is composed essentially of drift, deposited during the melting of the ice after the Ice Age, resting on a stratum of limestone which in many places comes to or near the surface. The soil partakes of the general nature of drift, containing a considerable proportion of sand and the usual amount of organic matter. It is, therefore, a soil which is peculiarly suited to the growth of potatoes—a soil which does not pack after hard rains nor during periods of drought. Its open and porous nature permits the free development of the tubers and the evolution of rootlets both lateral and perpendicular. The soil was originally covered with a growth of hard and soft woods consisting chiefly of maple, cedar, birch, white poplar, spruce, hemlock, and pine. The forest growth was dense, and in clearing large quantities of ashes were produced, which fitted the virgin fields particularly for the production of large crops of potatoes. After a few years of cultivation, the fields begin to lose a portion of their natural fertility, and the potatoes are grown in these fields at the present time with a liberal application of farm manures and commercial fertilizers containing a large percentage of potash. The commercial fertilizers which are chiefly used for potato growing have, according to determinations made in the Agricultural

[1] Total production, 1899, 15,500 tons: Maine and New Hampshire, 9,000 tons; New York, 400 tons; Wisconsin and other Western States, 6,100 tons.

Experiment Station of Maine, the composition shown in the following table:

Composition of fertilizers used in growing potatoes.

Trade name.	Nitrogen.		Phosphoric acid.		Potash.
	As ammonia or nitrate.	As organic.	Available.	Total.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Chittenden's ammoniated bone phosphate	0.57	1.47	9.47	10.78	2.26
Chittenden's complete fertilizer	1.45	1.98	8.52	10.24	6.47
Chittenden's market-garden fertilizer	.68	1.75	7.72	9.15	6.38
Darling's blood, bone, and potash	1.31	2.33	8.89	9.75	7.36
Coe's Columbian potato fertilizer	.11	1.40	9.83	12.25	2.11
Coe's high-grade potato fertilizer	.75	1.77	9.19	11.69	6.11
Maine State Grange potato manure	.75	.72	9.83	12.53	11.27
Quinnipac potato manure	.77	1.72	8.17	9.39	5.13
Sagadahoc special potato manure	1.03	1.11	6.96	10.96	7.60
Standard special	.47	1.73	8.96	11.32	3.08
Stockbridge potato manure	1.54	1.74	6.90	9.34	10.06
Williams & Clark's potato phosphate	.77	1.59	8.30	9.21	4.61
Young's Excelsior potato fertilizer		2.80	6.59	8.55	9.94

POTATO-STARCH INDUSTRY IN WISCONSIN AND ADJACENT STATES.

Wisconsin is one of the most important potato-producing States and stands next to Maine in the production of potato starch. In the immediate neighborhood of Stevens Point, in a triangular area of which each side is about 30 miles, there are over 60,000 acres of potatoes grown. Mr. Horace E. Horton, a resident of that locality, says:

This belt is composed of glacial drift. The land adjacent to the Wisconsin River is made up of level deposits of sand and gravel covered with a light loam. The sand is usually found underdrained by a bed of coarse gravel.

Back from the river are uplands, a rolling surface covered with drift composed of clay, sand, gravel, and bowlders, variously intermixed. Sandy loam prevails. Clayey loams occupy some areas, but are not prevalent.

The three great potato-producing counties are Portage, Waushara, and Waupaca, the acreage planted in 1899 being 25,026, 19,960, 15,702, respectively. As a further indication of the size of the industry, it is only necessary to state that Plainfield, in Waushara County, has shipped as high as 1,965 carloads in one season; Hancock, within 8 miles, 1,600 carloads. Waupaca, in Waupaca County, is second only to Plainfield in shipments. The average yield of potatoes is 100 bushels per acre.

This potato belt is reached by two railroads. The connection with Eastern consumers is the very best. A large part of the year, shipments are made by lake and rail.

The potato-producing area is rapidly increasing. New settlements are forming, and the potato is the natural plant to follow forests and grass lands.

Factories are operated at Stevens Point, Waupaca, Black River Falls, and Grantsburg.

The industry is technically more developed in the West than in the East.

There are no varieties of potatoes grown in Wisconsin for textile purposes. The starch factories must content themselves with the small, unripe, rotten, scabby stock, unfit for edible purposes. The starch content is low, and with good factories 8 pounds of starch a bushel is a big yield; the average yield is from 6 to 7 pounds.

The quality of the starch produced is not uniform; even in the same factory the quality varies from day to day. Mechanical impurities abound. For certain textile purposes domestic products can not be used, and consumers import European brands.

The history of the industry shows wrecks and is likely to show more in the immediate future. The danger line of production equaling consumption is dangerously near.

There are factories in the West in operation at the following points: Traverse City, Mich.; Waupaca, Wis. (2); Stevens Point, Wis.; Black River Falls, Wis.; Grantsburg, Wis.; Anoka, Minn. (2); Monticello, Minn. (11).

INFLUENCE OF COMMERCIAL FERTILIZERS ON THE QUALITY OF THE POTATO.

It is shown by the data contained in the analyses of potatoes from German sources, given farther on, that the use of commercial fertilizers influences the composition of the potato, especially in respect of the quantity of starch it contains. The value of potash in producing additional quantities of carbohydrates in growing plants has been pretty well established by experimental work. It is evident, therefore, that the liberal use of potash not only favors the growth of the potato in regard to yield, but also tends to increase the content of starch which it contains. The German experiments have indicated also that a moderate use of nitrogen tends to slightly increase the content of starch in the potato. An excessive use of nitrogenous fertilizers is to be avoided. Extensive experiments have been made in this direction by some of the agricultural experiment stations of the United States, especially in Maine and Virginia. In Bulletin No. 92 of the Virginia Agricultural Experiment Station the results of the experiments with fertilizers on the composition of the Irish potato are given. The conclusions which were reached at the Virginia station are as follows:

(1) That potatoes grown without fertilizers contain the greatest amount of dry matter. The addition of fertilizers tends to diminish the dry matter, and also as the quantity of fertilizer used is increased the amount of dry matter is diminished.

(2) Potatoes grown where sulphate of potash is used contain more dry matter than those where muriate is used.

(3) The ash is not affected to any very appreciable extent; fertilizers tend slightly to increase it.

(4) Very little effect is produced on the starch by either the kind or amount of fertilizers used; their tendency is to increase rather than to diminish it.

(5) Potatoes grown with muriate of potash contain less dry matter but slightly more starch than those grown with sulphate of potash.

(6) Neither the kind nor amount of fertilizers has any appreciable effect on the percentage of nitrogen, phosphoric acid, and potash contained in potatoes.

(7) The percentage of chlorin is considerably increased when muriate of potash is used, and the more muriate used the higher the per cent of chlorin.

THE COMPOSITION OF SOILS IN WHICH POTATOES ARE GROWN.

The study of a sample of soil representing any given area gives information only of the state in which it existed at the moment the sample was secured. Unless the field be a virgin one, the quality of the original soil is not revealed by the analysis. Even in the case of the virgin soils of Maine it has already been noted that their composition might be materially influenced by the large quantities of hardwood burned during the process of clearing. The content of potash, phosphoric acid, lime, and magnesia might thus be unevenly distributed. Several years of cultivation and cropping would be necessary to secure a fairly uniform admixture of these ingredients with the soil, even supposing that any excess of the more soluble portions were not removed by the rainfall.

The following data show the results of the analyses of samples of soil furnished by Director C. D. Woods, of the Maine station:

Composition of two samples of Maine soils.

[Analyses by C. C. Moore and T. C. Trescot.]

Constituents.	Serial No. 17554.*a*	Serial No. 17555.*a*
	Per cent.	*Per cent.*
Insoluble	81.15	81.14
Volatile *b*	8.14	8.16
Ferric oxid (Fe_2O_3)	4.33	4.43
Alumina (Al_2O_3)	3.81	3.73
Manganic oxid (Mn_2O_3)	.09	.09
Lime (CaO)	.43	.48
Magnesia (MgO)	.84	.76
Sulphuric acid (SO_3)	.15	.15
Phosphoric acid (P_2O_5)	.15	.15
Potash (K_2O)	.30	(*c*)
Soda (Na_2O)	.12	(*c*)
Carbonic acid (CO_2)	.16	.15

a A qualitative test showed the presence of arsenic.
b Containing nitrogen as follows: Serial No. 17,554, 0.24 per cent, Serial No. 17,555, 0.23 per cent.
c Not determined.

The above data show that the soils are siliceous but contain a considerable quantity of organic matter. They are reasonably rich in lime and magnesia, which seem to be essential constituents of a soil suited to the growth of potatoes. The potash is also in fair quantity, but not sufficient to produce maximum crops.

The two samples of soil are practically identical in composition, and hence it was not deemed necessary to determine the alkalis in the second sample. The data show that the figures for the first sample could be inserted with perfect propriety to represent the second one.

The presence of arsenic in both samples of soil indicates the use of paris green or some arsenical insecticide to protect the growing potato vines from insect pests. The accumulation of arsenic in a soil as a result of the use of arsenical insecticides is a question of considerable hygienic importance. It is not improbable, from what is known of the tendency of plants to absorb soil constituents, that the presence of a considerable quantity of arsenic in soils might, by the absorption of the arsenic in the growing crop, result injuriously to the consumers of the food products. The use of Bordeaux mixture on the potato vines to prevent the development of molds and rots is also a subject worthy of study and has been considered in detail by the Maine station in a bulletin which has just been issued.

AGRICULTURAL DATA.

PREPARATION OF SOIL.

The plowing of the potato fields is accomplished chiefly in October and November, until freezing prevents further work. The soil is plowed to a depth of 6 or 8 inches and reduced to a proper tilth by harrows. In this condition it is left during the winter. When there are early snows protecting the soil from the cold, frost does not penetrate to a very great depth, so that upon the melting of the snows in the spring the soil is soon ready for cultivation. If the snows of the early winter be small in quantity the frost penetrates to a greater depth, and this prevents the early planting of the potatoes in the following spring.

SEED.

The potatoes which are used for seed are kept over winter in houses specially built for the purpose. These houses are built above ground and consist of a double wall of boards, with a space of about 6 inches between them, which is filled with sawdust. The room holding the potatoes is built over a cellar, in which a stove can be placed for use during the coldest days of winter. The potatoes are kept in bins, which may hold several hundred barrels each. The walls of these bins do not come in contact with the inner wall of the potato house, but an air space is left between them. Between these bins air holes are bored in the floor, connecting with the cellar, so that the air which is warmed by the stove can rise and circulate in the air space between the potato bins and the inner wall of the house. The object of this is to prevent the freezing of the potatoes in the very cold periods of winter, when the thermometer sometimes falls to 30° or 40° below zero. The further object, however, is to keep the potatoes as cool as possible, only a few degrees above the freezing point. In fact, the temperature may fall for a short time to two or three degrees below the freezing point without danger of injuring the potatoes, since the heat produced by their vital activity is sufficient to protect them against a slight degree of freezing. In Wisconsin, brick warehouses are preferred.

The Aroostook County (Me.) seed potatoes are well known in all parts of the country, and large quantities of them are annually sold in other States for seed production. One farmer during the spring of

1898 sent 14 carloads of seed potatoes to Texas. Freights on shipments are reasonably low, the rate to Boston being 21 cents per 100 pounds. Where a single barrel only is sent the rate to Boston is 85 cents per barrel. Shipments are made mostly in bulk, or, where the potatoes are to be transferred to a boat, in sacks.

TIME OF PLANTING.

The potatoes are planted chiefly during the month of June. This gives ample time for their growth and maturity by the first or middle of September, when the harvest begins. The planting is done in rows 30 inches apart, by means of a potato dropper. The potatoes which are used for seed are usually cut into two or more pieces before planting. (Pl. I.) When a fertilizer is employed the drill dropping the potatoes also places the fertilizer in the row. Fertilizers are not used broadcast. By the use of the machine above mentioned the planting takes place with great rapidity, a man and two horses being able to plant from 6 to 8 acres per day.

CULTIVATION.

When the potato tops show above the ground they are first covered lightly by means of a plow. On making their second appearance they receive ordinary cultivation with a horse cultivator and a horse hoe to keep out the weeds and keep the surface of the soil well stirred, the final cultivation being secured by throwing the soil against the plants and forming a ridge. The whole of the cultivation is by means of horse plows and hoes, the hand hoe not being used except in isolated instances. A good team and driver are able to cultivate about 20 acres of potatoes.

HARVESTING.

The potatoes are harvested with a digger, which enters the ridge far enough to lift the deepest potatoes to the surface. The soil and potatoes together are first received on a platform built in the shape of a grating, the spaces between the bars being large enough to permit the soil to pass through, but holding all the potatoes except those too small for the market. This table is given a shaking motion, so as to break up the soil and have it pass speedily through the bars. Several different kinds of harvesting plows are employed, but the general principles upon which each one is built are as described above.

ROTATION.

In many instances potatoes are grown exclusively for several years on the same soil. Usually, however, a rotation is practiced, of which the following is a type: Potatoes, oats, grass, the field being kept in meadow for two years. Clover is often sown with the oats, and flourishes in the vicinity of Aroostook County. In the fourth or fifth year the land is again planted to potatoes. Other methods of rotation are also practiced, but they do not differ essentially from that just described.

The following are plans of rotation followed on two German farms growing potatoes for the manufacture of alcohol and starch:

1. Wheat.	1. Potatoes.
2. Wheat and rye.	2. Potatoes.
3. Potatoes.	3. Potatoes.
4. Peas.	4. Potatoes.
5. Rye.	5. Fallow.
6. Potatoes.	6. Clover.
7. Barley and oats.	7. Clover.
8. Red, and white, and yellow clover; timothy.	8. Meadow.
	9. Beans.
9. Grass.	10. Rye.

In the first instance it will be seen that potatoes are grown twice in 9 years, namely, in the third and sixth years of the rotation. In the second scheme the potatoes are grown for 4 years in succession, and then for 6 years other crops are grown in the order shown.

YIELD.

The yield of potatoes varies greatly with the character of the soil and the season. Ninety barrels per acre are considered a satisfactory yield, and this is above the average. The barrel holds 2½ bushels, and the bushel weighs 60 pounds. Ninety barrels of potatoes, therefore, represent a weight of 13,500 pounds per acre. It has been found that in many localities in Aroostook County the yield of potatoes is diminished by the blight. Spraying repeatedly with Bordeaux mixture practically prevents the blight and greatly increases the yield.

POTATOES USED FOR STARCH MAKING.

Unless the price of marketable potatoes be very low, only the small, injured, or refuse potatoes are sold to the starch factory. Whenever the price of good merchantable potatoes is above 50 cents per barrel the farmers find it more profitable to sell directly to the market. During the time of this investigation good marketable potatoes were selling for $1 a barrel, and the starch factories were paying from 30 cents to 60 cents per barrel for the refuse. It is evident, therefore, that the yield from the weight of potatoes entering the factory is very much smaller than it would be if the whole crop of potatoes were used for starch making.

AREA UNDER CULTIVATION.

The estimated area planted to potatoes in Maine in 1898 was 45,946 acres; in 1897, 41,769 acres, and in 1896, 49,140 acres. The estimated quantity of starch made during 1898 was 6,000 tons. During the period from September 1 to the latter part of October an average of 60 carloads of potatoes a day had been shipped out of the county.

STARCH FACTORIES.

The number of starch factories in Aroostook County is about 45, and the average cost of a factory complete is approximately $13,000.

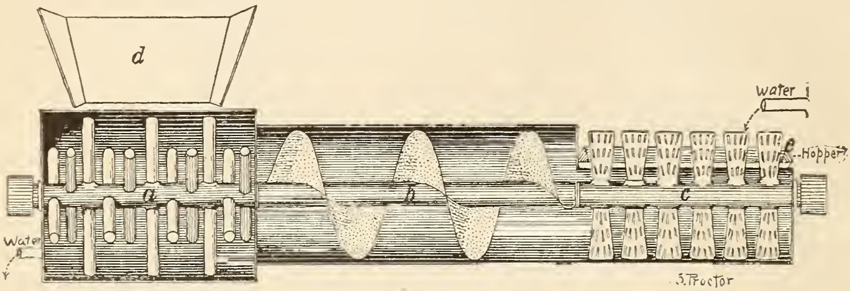


FIG. 1.—Machine for washing potatoes: *a*, spiral of arms for removing dirt; *b*. perforated screw for moving potatoes toward end of washer next to the comminutor; *c*, perforated paddles for lifting the clean potatoes into the hopper leading to comminutor; *d*, hopper for introducing potatoes into washer; *e*, hopper leading to comminutor.

The average capacity of the factories is about 1,200 bushels of potatoes a day, making a little over 20 barrels of starch of about 600 pounds each. The average yield of commercial starch is 16 per cent of the weight of potatoes employed, the starch holding from 16 to 20 per cent of moisture. This yield is secured only when potatoes of the best grade are used. Poorer potatoes yield only from 6 to 7 pounds per bushel of 60 pounds.

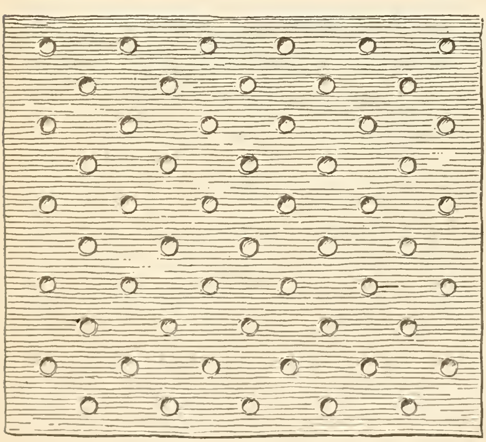


FIG. 2.—Section of surface of comminutor.

PROCESS OF MANUFACTURE.

The process of manufacture is extremely simple. The potatoes, which are kept in a storehouse, are carried, after weighing, to a revolving washer about 12 feet in length and from 18 to 24 inches in diameter. They are pushed toward the comminutor through the washer by means of a perforated spiral or by arms attached to a revolving axle. A stream of water flowing in a direction opposite to that of the motion of the potatoes secures the final washing with clean water. The principle of the washing apparatus is shown in fig. 1. By the time the potatoes have reached the comminutor they are practically free from dirt and grit.

The rasping machine consists of a cylinder about 30 inches in diameter and 36 inches long. This cylinder is made of wood and is covered with pieces of sheet iron punched full of holes about one-eighth of an inch in diameter, as indicated in fig. 2. The rough edges of the iron, resulting from the punch, face outward. These pieces of iron are nailed on the cylinder in sections, and when they have become dulled by use they are taken off and replaced by new sheets. The rate of revolution of the cylinder is about 600 per minute. Some of the rasps are much larger than the one just described, the one at Brown's factory, in Holton, having a capacity nearly double that just noted. The principle of the construction, however, is exactly the same.

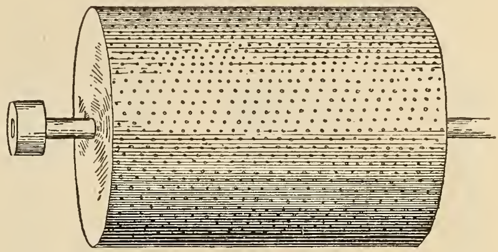


FIG. 3.—Rasping cylinder or comminutor.

The rasping cylinder, with the iron rasps attached, is shown in fig. 3.

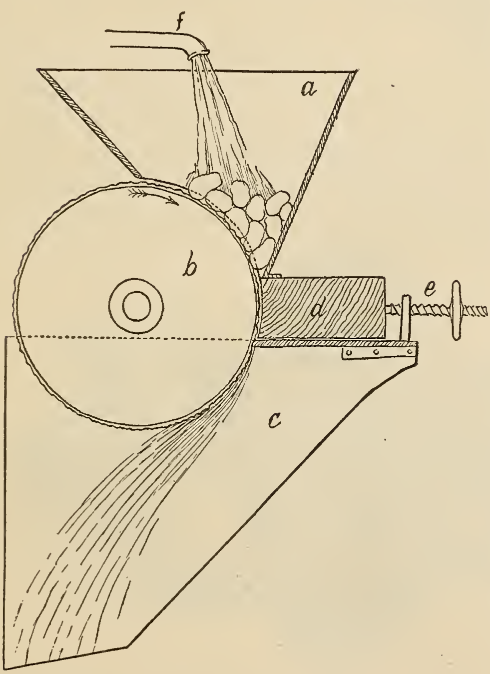


FIG. 4.—Rasping machine (cross section): *a*, hopper; *b*, rasp; *c*, receptacle for pulp; *d*, buffer; *e*, setting screw; *f*, water jet.

The rasp revolves as near a brace of hardwood as can be, and the potatoes, being stopped by the brace from passing, are reduced to a fine pulp by the rapidly revolving drum (figs. 4 and 5). Some of the modern factories have specially constructed rasps which are more effective than those just described. The potato-starch factories of Stevens Point, Wis., use a large-size rasp made in Leipzig and having a capacity of 250 bushels an hour. Other factories in the West use the grater shown in fig. 6. A stream of water is thrown upon the potatoes as they enter the comminutor, so that the pulp is readily washed through as it is reduced to the required degree of fineness.

The various parts of the comminutor are shown in cross section in fig. 4: *a* represents the hopper holding the potatoes; *b* the wood cylinder or rasp which revolves at a high rate of speed; *c* the hopper in which the potato pulp is received after passing the rasp; *d* the wooden press which is kept in position by means of the screw *e*; through the pipe *f* comes the water which aids in carrying potatoes through the rasp. The horizontal section of the rasping machine is also shown in fig. 5. Another and more compact form of potato rasp is shown in fig. 6.

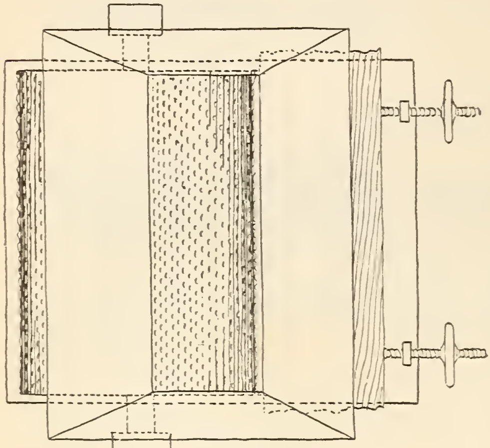


FIG. 5.—Plan of rasping machine.

The pulp falls from the rasper onto a starch separator, the bottom of which consists of wire gauze having thirty meshes to the inch (fig. 7). The meshes, however, are not the thirtieth of an inch in diameter, since the thickness of the wire must be deducted therefrom, making the openings of the mesh about one-sixtieth of an inch in diameter. This separator is slightly inclined, so that the shaking process gradually moves the pulp toward the lower end. The starch separator is of the same width as the rasps, namely, about 36 inches, and is 12 feet in length. During the progress of the pulp along the separator, jets of water

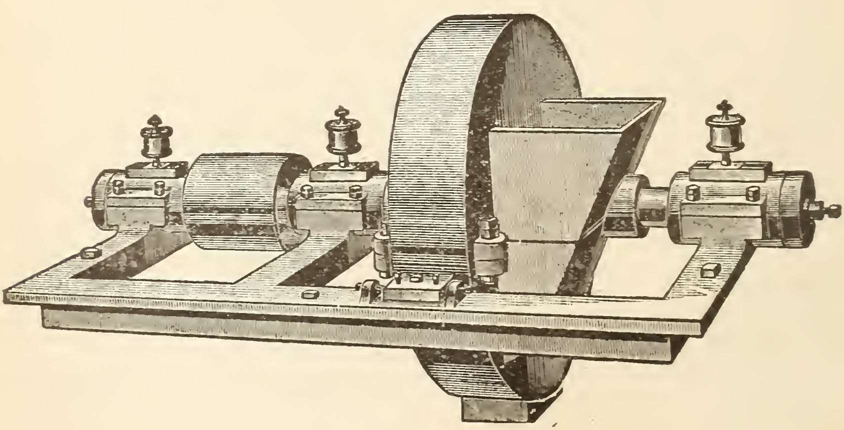


FIG. 6.—Potato grater.

are thrown upon it from pipes arranged above. The water detaches the starch granules from the pulp, and the granules, being small enough to pass through the meshes of the gauze, are carried through, while the pulp is left upon the screen, to be ejected finally at the lower end. The arrangement of the separator and water jets is shown in fig. 7.

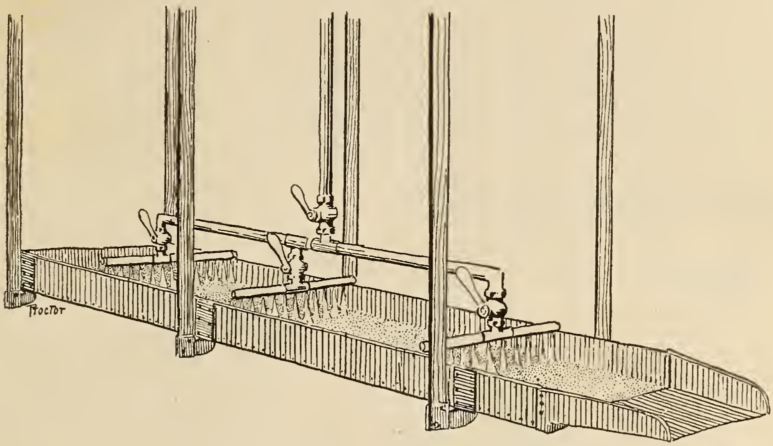


Fig. 7.—Starch separator.

The pulp, which is a useful cattle food, is thrown away at all the factories in Aroostook County. It does not pay to preserve it in a country where other forms of cattle food are so cheap. The best hay sells at the market in Presque Isle for $5 a ton.

In Wisconsin and some of the other Western States, the potato factories are situated on trout streams, and they are forbidden to run their refuse into these streams. In such cases, the refuse is collected in large cisterns dug in the ground. The potato pulp can be fed in fresh condition without bad effect to milk cows or to steers. With a little care it can also be given to sheep, but usually it is allowed to go to waste.

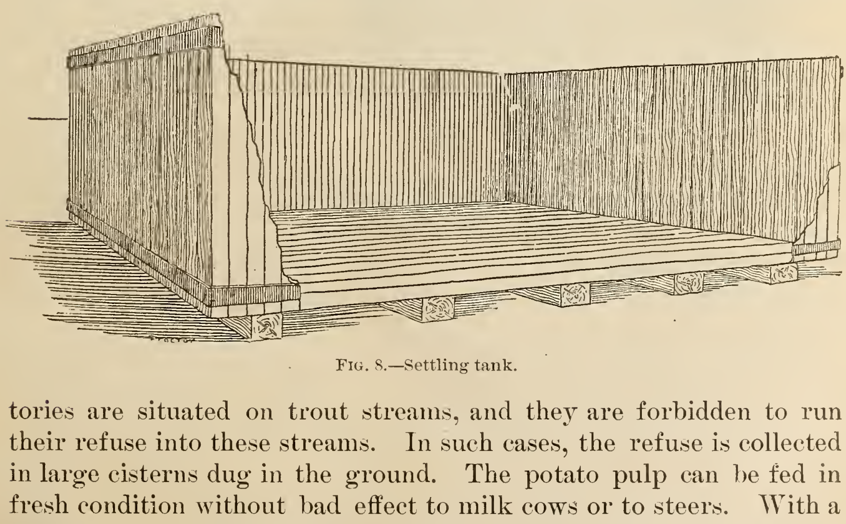


Fig. 8.—Settling tank.

SETTLING TANKS.

The starch, which is carried through by the water, falls into large tanks. These tanks, a type of which is shown in fig. 8, are of various sizes, namely, from 20 to 40 feet in length and width and from 6 to 8 feet in depth. The starch, when it enters these tanks with the water, rapidly settles to the bottom, and the reddish-colored supernatant water can be drawn off. In a few hours after the tank is filled the starch is all settled in a hard, compact mass in the bottom of the tank. The proportion of starch and water is such that a 4-inch layer of starch will result from a quantity of starch milk which would fill the tank. In other words, 4 inches of starch are overlaid with about 6 feet of water.

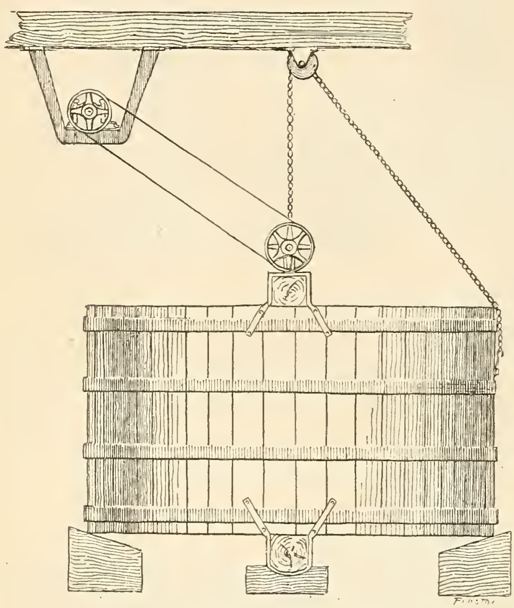


Fig. 9.—Starch washer (exterior view).

The crude starch resulting from the above process, after the water is drawn off, is lifted by shovels and thrown into another tank of somewhat smaller size fitted with a revolving stirrer; water in large quantities is added at the same time, and the starch is beaten into a cream and again allowed to settle. (Exterior and interior views of this washing tank are shown in figs. 9 and 10.) This process is simply for washing the starch and removing the larger portion of impurities. In the second settling the pure white starch first goes to the bottom, and when the water is drawn off it is found to be covered with a thin layer of starch mixed with various forms of impurities. This layer is removed separately, and the pure starch underneath is ready for the drying tables.

The layer of dirty starch removed as above indicated is subjected to a second washing, and, if necessary, to a third, the final separation of the starch which it contains being sometimes effected in starch separators of the usual construction. These are so constructed that the starch cream poured upon them permits the separation of the starch during the flow of the liquid, so that by the time the end of the screen is reached the starch is practically deposited and the dirt and refuse flow away.

DRYING THE STARCH.

The white starch derived from the process just described is dried in kilns of two kinds. The old-fashioned kilns were heated directly by furnaces, the hot air coming from the pipes being used to dry the starch. In the modern kilns, the drying is effected by means of steam coils. These permit a more uniform and more rapid drying, and at the same time diminish the danger of fire, which is very great in the kilns heated directly by furnaces. During the present season (1899) three furnace kilns have been burned in Aroostook County. Very few furnace kilns are now under construction, most of the new ones being provided with steam heaters. The kilns are usually erected at a distance of 100 yards or more from the factory, so that in case of fire the factory building may not be destroyed.

In fig. 11 is seen the end view of the drying kiln, looking back from the fan *c*, which forces the air onto the steam coils *a–a*. The entrance of the air is so arranged by a conduit (not shown) as to cause the whole of it to pass over the coils *d*, in which very cold water circulates. The air in passing over the cold pipes *d* loses a great part of its moisture, so that it is as dry as possible on reaching the heating coils *a–a*.

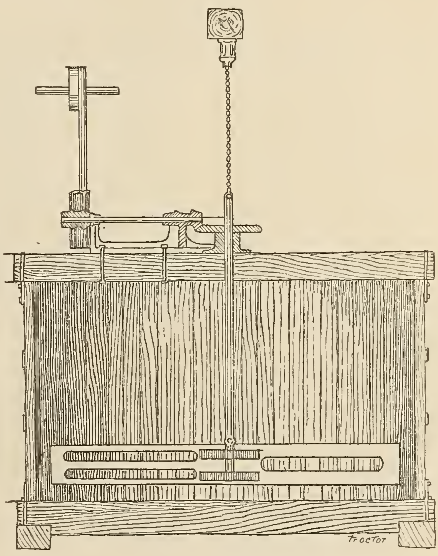


FIG. 10.—Starch washer (interior view).

The different platforms or shelves on which the starch successively falls are shown at *e–e–e–e*. Each shelf is easily reached by doors, the hinges of which are shown at *f–f–f*, so that the starch can be easily raked and made to fall through the spaces between the slats of the shelves, as shown in the figure. The bottom shelf is a solid floor, so that the dried starch can be finally delivered into the troughs *b–b*, which extend along the full length of the drying kiln.

Fig. 12 shows an end and side view of the drying apparatus, the details of which have been sufficiently indicated in the description of the preceding figure.

Fig. 13 shows the top floor of a kiln heated by direct fire, the chimney of the furnace appearing near the back of the engraving. This illustration is drawn directly from a photograph.

Fig. 14 shows the top floor of a steam drying kiln, drawn from a photograph taken soon after the operation of placing the blocks of starch upon the floor was commenced. Another form of top floor is shown in fig. 15, in which not only is the floor itself covered with the blocks of wet starch, but in order to increase the drying space, shelves are erected on which additional quantities of wet starch can be placed. This illustration is also drawn from a photograph. All of the illustrations above mentioned were obtained from photographs of the factories in Aroostook County, Me.

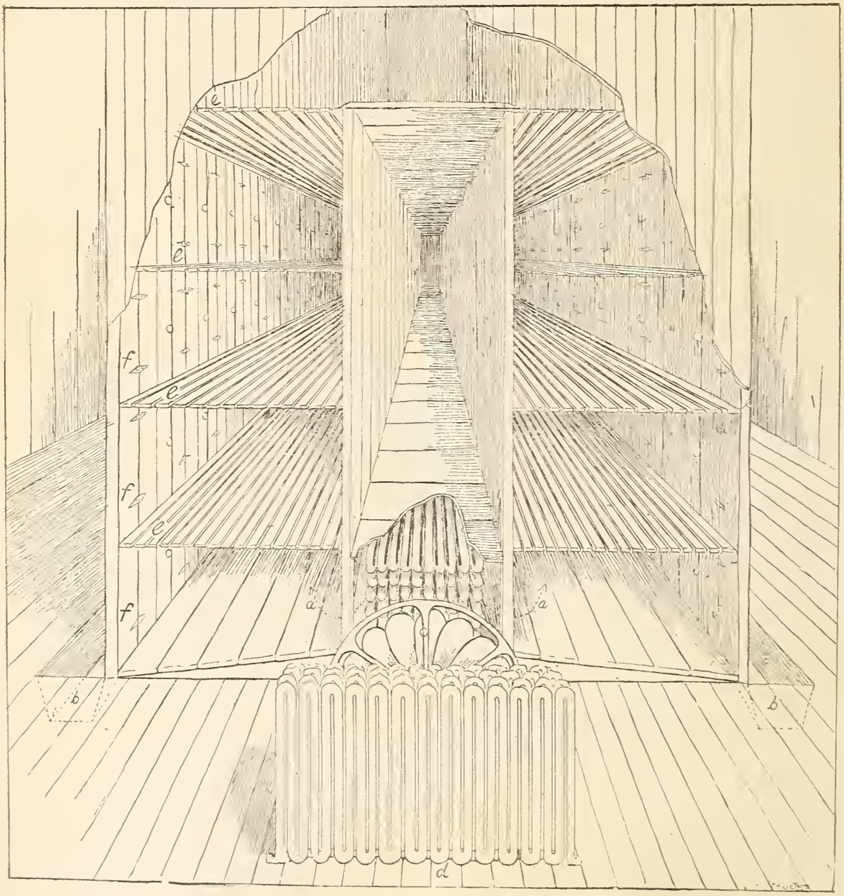


FIG. 11.—Drying kiln (end view).

After a few hours' drying the large blocks of wet starch fall down in smaller portions on raking, and these smaller portions fall through the slats, shown in the figure, and are caught upon the shelves below. Thus, little by little, the starch which is raked through the shelves becomes drier and drier and is brought into contact with the hot air.

In this way the starch granules are protected from swelling and conversion into a pasty mass, as would otherwise be the case if they were subjected in the wet state to the full temperature of the final drying.

SUMMARY OF THE TREATMENT OF THE STARCH UPON THE FLOORS.

The starch is placed first upon the upper floors, on wooden slats with openings of about half an inch. This is the coolest part of the kiln, so that the starch containing the greatest amount of moisture is subjected to the least degree of heat. It is not safe to submit very wet starch to a high temperature, for there would be danger in this case of converting it into paste and rendering it unfit for market. When the starch is partially dried it is raked over the grated floor, and the particles which are dry enough to be easily detached fall through and strike similar grates below. This process of raking over the various layers of starch continues until the starch in a fine powder finally reaches the lower floor in a state of dehydration suitable for barreling.

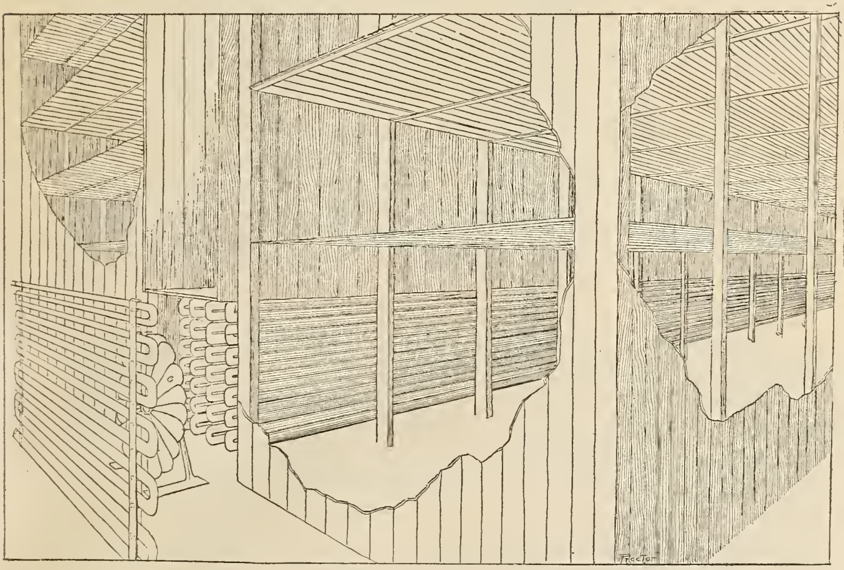


FIG. 12.—Drying kiln (end and side view).

It requires about twelve hours to complete the drying when the most effective kilns are employed, so that the kilns are charged with the wet starch, as a rule, twice a day. The size of the kilns is, of course, proportionate to the capacity of the house. For a house using 1,200 barrels of potatoes a day the kilns are about 40 feet long and 30 feet wide, and the shelves on which the starch is dried are about 15 feet in height.

The dried starch is finally raked off of the lower floor into a trough along the side of the kiln, whence it is placed in the barrels already mentioned. In some of the steam kilns the drying is accelerated by a blast produced by a blowing fan. The cold air, before being forced into the kiln by the fan, is passed over a series of iron tubes filled with cold water, which takes from the air a considerable proportion of moisture which otherwise would enter the kiln. It is evident, from the description of the kiln which has been given, that the hottest and dryest air strikes the dryest starch first, the air being successively cooled and becoming more and more saturated with moisture as it passes upward to the wetter layers of starch.

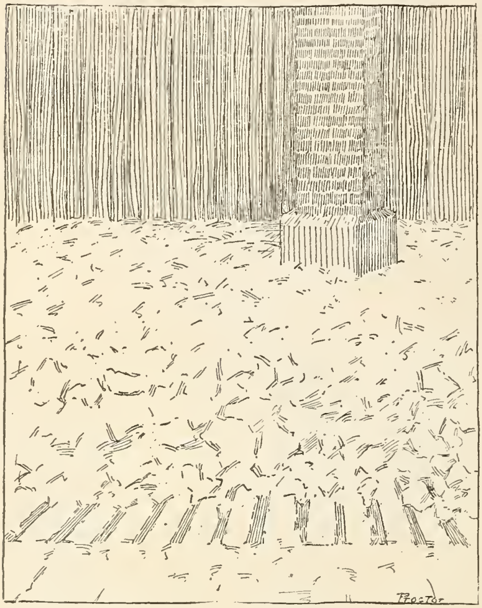


FIG. 13.—Upper floor of drying kiln.

The wet starch in lumps of various sizes is transported over a bridge connecting the kiln and factory, either on a small railway or, more often, in wheelbarrows, as shown in Pl. II, fig. 1.

BARRELING AND SHIPPING THE STARCH.

After the starch is thoroughly dried, it is carried to the warehouse, where it is placed in heaps, in order that the moisture may be evenly distributed throughout the mass. It is evident from the method of drying that some parts of the starch come from the kilns much drier than others. If the barreling take place at once, the percentage of moisture in the marketed product is not uniform. Uniformity of moisture is secured by placing the starch in large warehouses, where it resembles banks of driven snow, as shown in Pl. II, fig. 2, from a photograph of such a warehouse taken in Aroostook County.

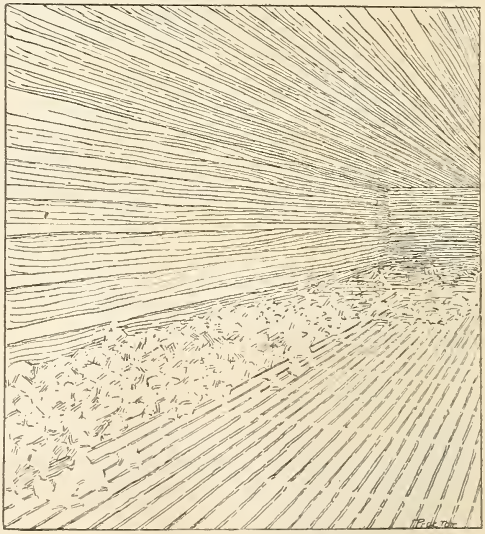


FIG. 14.—Starch drier (upper floor).

After the mass of starch has become uniform in its content of moisture, it is placed in barrels, and is then ready for transportation. The appearance of the product at this time is shown in Pl. III, fig. 1, from

FIG. 1.—TRANSPORTING STARCH TO THE KILN.

FIG. 2.—STARCH WAREHOUSE.

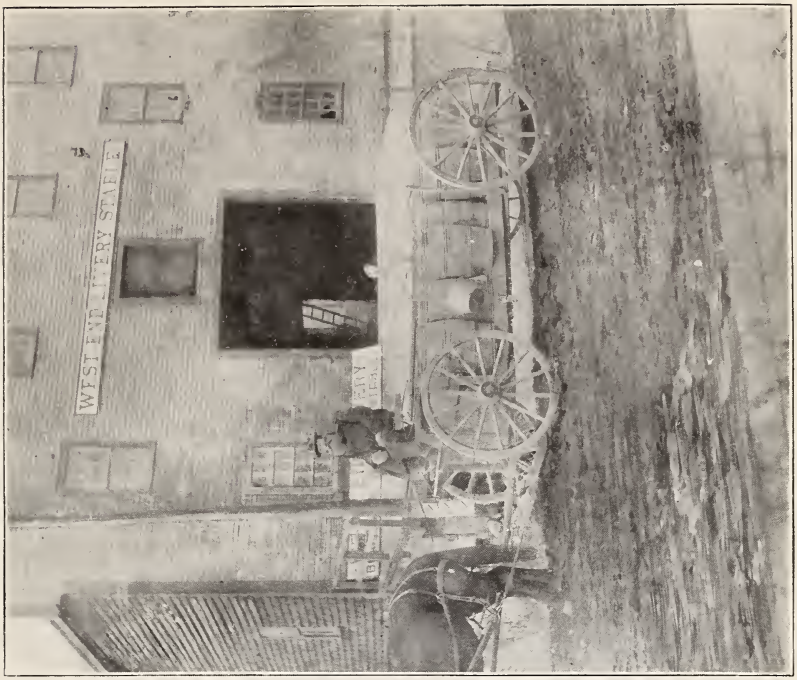


FIG. 2.—WAGON LOADED WITH STARCH.

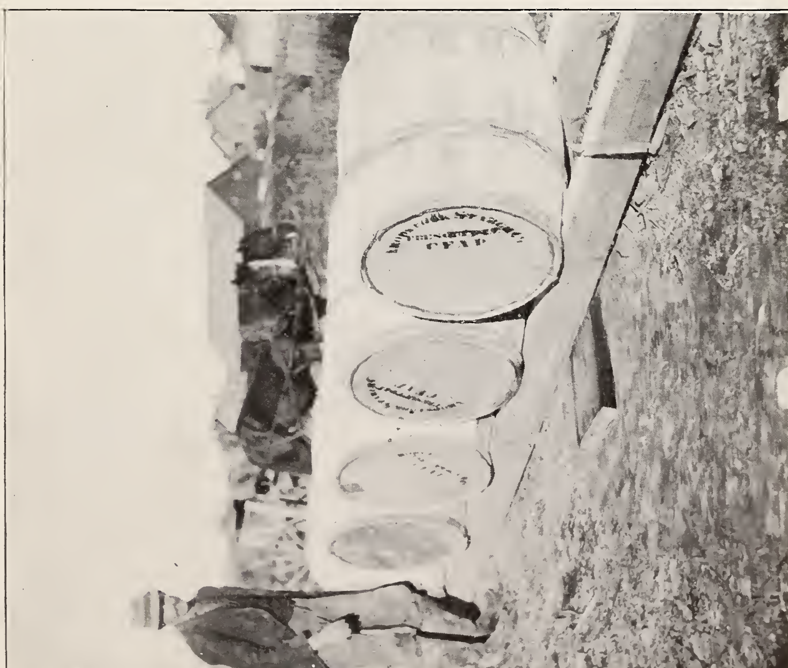


FIG. 1.—BARRELS OF STARCH READY FOR LOADING ON WAGONS.

a photograph taken in front of a starch warehouse at Presque Isle, Aroostook County, Me.

For convenience in handling the barrels, a peculiar form of wagon is used by the farmers for transporting the starch. This wagon is characterized by a low platform, which makes it very convenient to handle the starch, which, on account of its specific gravity, is extremely heavy when barreled. A wagon of this kind charged with its load is shown in Pl. III, fig. 2, taken from a photograph secured in Presque Isle, Aroostook County, Me.

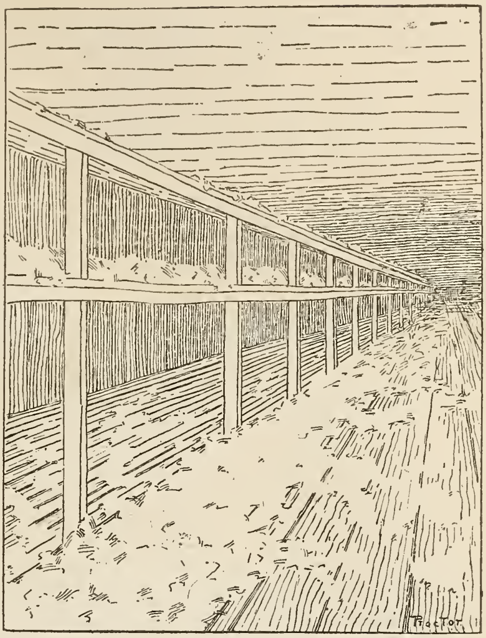


FIG. 15.—Starch drier (upper floor), with shelving.

THE PRICES OF VARIOUS KINDS OF STARCHES AND OF DEXTRINS.

The wholesale prices of the principal starches and dextrins in the United States for the several months of the year 1899 are given in the following table:

Extreme wholesale prices of the principal commercial starches and dextrins for the year 1899.

[Compiled from the weekly quotations of the Oil, Paint, and Drug Reporter.]

Month.	Starches.						Dextrins.		
	Corn, pearl, in barrels.	Potato.	Rice.	Wheat.	Sago flour.	Tapioca flour.	Imported.	Domestic.	Corn.
	Cts. per lb.	*Cts. per lb.*	*Cts. per lb.*	*Cts. per lb.*	*Cts. per lb.*	*Cts. per lb.*	*Cts. per lb.*	*Cts. per lb.*	*Cts. per lb.*
Jan	1.40–2.00	3½ –4	....	5–6	3½ –3⅞	4 –4½	5¾ –7	5¼ –6	2.15–3
Feb	1.40–1.60	3⅞ –4¼	....	5–6	3⅞ –4¼	4¼ –4¾	6 –6¼	5¼ –5¾	2¼ –3
Mar	1.40–1.60	4 –4½	....	5–6	4 –4¼	4½ –5	6 –6¼	5¼ –5¾	2¼ –3
Apr	1.45–1.60	4¼ –4¾	....	5–6	4 –4¼	4½ –5	5⅞ –6⅛	5¼ –5¾	2⅜ –3
May	1.43–1.60	4½ –4¾	....	5–6	3⅞ –4¼	4½ –5	5⅞ –6⅛	5½ –6	2⅜ –3
June	1.40–1.65	4½ –4¾	7½–8½	5–6	3¾ –4	4½ –5	5⅞ –6⅛	5½ –6	2½ –3
July	1.44–1.65	4½ –4¾	7½–9	5–6	3¾ –4	4¾ –5	5⅞ –6⅛	5½ –6	2½ –3
Aug	1.44–1.65	4½ –4¾	7½–9	5–6	3¾ –4	4¾ –5	5¾ –6⅛	5½ –6	2½ –3
Sept	1.39–1.60	4½ –4¾	7½–9	5–6	3¾ –4	4¾ –5	5¾ –6	5½ –6	2¼ –3
Oct	1.45–1.60	4 –4¾	7½–9	5–6	3⅜ –3¾	4⅞ –5¼	5¾ –6¼	5¼ –6	2¼ –3
Nov	1.55–1.60	4 –4¾	7½–9	5–6	3⅜ –3¾	4⅞ –5¼	5¾ –6¼	5¼ –6	2⅜ –3
Dec	1.52–1.60	4 –4¾	7½–9	5–6	3½ –3¾	4⅞ –5¼	5⅝ –6¼	5½ –6	2⅜ –3
Minima	1.39–1.50	3½ –3¾	7½–8½	5–6	3⅜ –3¾	4 –4¼	5⅝ –6	5¼ –5½	2.15–2.25
Maxima	1.55–1.65	4½ –4¾	7½–9	5–6	4 –4¼	4⅞ –5¼	6¼ –7	5½ –6	2½ –3
Means	1.46–1.61	4.21–4.57	7½–9	5–6	3.73–3.98	4.63–4.96	5.87–6.17	5.40–5.88	2.37–2.96

From the above table it will be noticed that there are very wide ranges in the prices of starches of different origin, the indian-corn starch of the highest grade being the cheapest of all, while rice starch commands the highest price.

Dextrin, or British gum, is one of the principal products derived from starch. The price of this article also varies greatly, the imported dextrin and dextrin of domestic origin made from other starches than indian corn commanding the highest price, the imported article, which is made almost exclusively of potatoes, having the highest price of all. On the other hand, domestic dextrin made from indian-corn starch is only a little over half as valuable as the others.

USES OF POTATO STARCH.

Potato starch possesses peculiar properties, rendering it especially valuable for use in print works. Nearly all of the potato starch manufactured in Aroostook County is sold to print works in Massachusetts, Rhode Island, and other parts of New England. The makers of prints are willing to pay a considerable increase in price for potato starch over that which they would have to pay for starch made from indian corn. This higher value has led, according to information received from several quarters, to the adulteration of potato starch with indian-corn starch to a considerable extent.

In order to more fully present the valuable properties of potato starch in the print works, the writer asked Mr. John Alden, a chemist of mills at Lawrence, Mass., for a statement in regard to this matter. In compliance with this request, Mr. Alden has kindly furnished the following information in regard to the uses of potato starch in the print works:

POTATO STARCH IN THE TEXTILE ARTS.

(1) Potato starch is used in the manufacture of cotton, woolen, linen, and silk goods for three distinct purposes, viz: First, as a sizing for the warp yarn before it is woven; second, for finishing the goods after they have been woven, bleached, dyed, or printed; third, in the form of dextrin or roasted starch, as a thickener or vehicle for applying the colors to the fabric.

(2) The preparation of starch for sizing and finishing consists mainly in mixing it with the proper amount of water in a wooden or metal tank, which is provided with a perforated metal pipe for blowing in steam so as to properly cook the starch, or else the cooking is done in an iron or copper kettle provided with a double bottom for heating by steam under pressure, and also provided with a stirring apparatus for keeping the ingredients of the size or finish properly mixed during the cooking. The starch mixture is boiled from ten minutes to an hour or more, as the size maker may deem best, and, after straining to remove any lumps or gritty matter, is ready for use in the sizing or finishing machine. Besides the starch and water, various other substances are added to impart peculiar qualities to the size. Thus, to give softness to the sized or finished yarns or fabric, it is customary to add some oil or fat, as tallow, cocoanut oil, bone fat, or even soaps, before or during the boiling, while various hygroscopic agents, such as glycerin and the chlorids of magnesium, zinc, or calcium, are added to prevent the size from drying too much, so as to be harsh, stiff, and brittle. The latter salts also act as antiseptics on heavily sized yarn or goods, preventing the souring or mildewing which is liable to take place when the goods are stored in a damp place. When it is desired to make the yarn or fabric seem heavier than it does in its normal state, or to give the goods more body—i. e., make them

appear thicker and more closely woven—various white pigments are added to the size, such as china clay, whiting, etc. Finally, to make the goods appear whiter, by taking away the slightly yellowish tint of the natural fiber, even after it is bleached, certain blue or bluish violet coloring matters are added to the size or finish, chiefly ultramarine or prussian blue.

The above represents, in general terms, the composition of the sizes and finishes, though each individual sizer and finisher has his own receipts, which he considers to be essential to his own particular requirements, and a list of the ingredients used in those receipts would cover almost every chemical known. It is quite an art to be able to size or finish a fabric so as to imitate any sample that may be furnished, no matter whether the fabric and fiber are the same or totally different. It is the business of the expert in charge of the sizing to make a piece of cotton feel and look like a wool or silk fabric, if he is requested to do so.

The third use of potato starch mentioned above, its use in the form of dextrin for thickening colors, is no longer a very important one, as the various indian-corn dextrins have replaced the potato almost altogether, owing to their cheapness and greater thickening power. For very fine light work, especially in silk and wool printing, potato dextrin still holds its own on account of its lighter color and closer resemblance to gum arabic in its thickening properties. Its greater freedom from smell is also an advantage in certain sizing work. Potato starch itself is very little used in printing, indian corn and wheat being the starches almost universally used. They resist the action of chemicals better and give a more satisfactory working paste, besides being much cheaper.

There is rather an interesting survival of an old process very frequently carried out in connection with the preparation of potato and indian-corn-starch sizes, an operation which accomplishes no particular object in its present use, although it had a specific purpose in its original application. I refer to the practice which holds in some mills of fermenting or souring their starch before boiling it up. In England, wheat flour has for a long time been the principal agent used in the preparation of sizes for warps. The English have a practice of sizing their warps and also of finishing their plain cotton cloth very heavily, so that in case such goods are exposed to a moist warm atmosphere they are exceedingly apt to sour and even mildew. As is well known, flour contains quite a proportion of gluten and other nitrogenous matters which are very prone to decomposition, and it was found very early in the use of sizes that by subjecting the flour to a preliminary souring or fermentation process before it was boiled up into size, these nitrogenous matters would be broken up, decomposed, and a size could thus be formed which would be very much less susceptible to souring. Potato and indian-corn starch do not contain enough gluten or nitrogenous matters to warrant this long tedious operation, and while it is true that the souring process produces some slight changes in the starch itself, converting a small proportion of it into dextrin and maltose, thus modifying to a slight extent the character of a size produced from a soured starch, the same result can probably be produced in a much simpler way by the addition of a small proportion of dextrin to the starch when it is boiled up. The souring process has been discarded in a great many American mills.

(3). The sizing of the yarn is an intermediate operation between the spinning and the weaving. As the yarn leaves the spinning frame it consists of a series of fibers more or less twisted together, the ends of the individual fibers standing out from the thread so as to make rather a hairy appearance. In order to stick down these loose ends and so make a smooth strong thread which will resist the wearing action of the shuttle as it rubs swiftly over it, and also the chafing action of the reed and harness, it has been the custom from the earliest times to give the warp thread a coating of some cementing material, called the size, the operation being called the sizing or dressing of the warp. The size, having been properly prepared and boiled, is run boiling hot into a trough at the front end of the sizing machine. This trough is supplied with a steam pipe for keeping the size at a boil, also with rollers for forcing the yarn under the surface and squeezing it thoroughly into the fiber of the yarn. As the yarn leaves the trough it passes between another pair of squeeze rollers to remove the excess of size, then between slats to separate the individual yarns from each other so that they will not be all stuck together, and then it is passed over drying cylinders to thoroughly dry it, and finally wound on a wooden roll at the end of the machine. This roll is put at the back of the loom when it is ready for weaving.

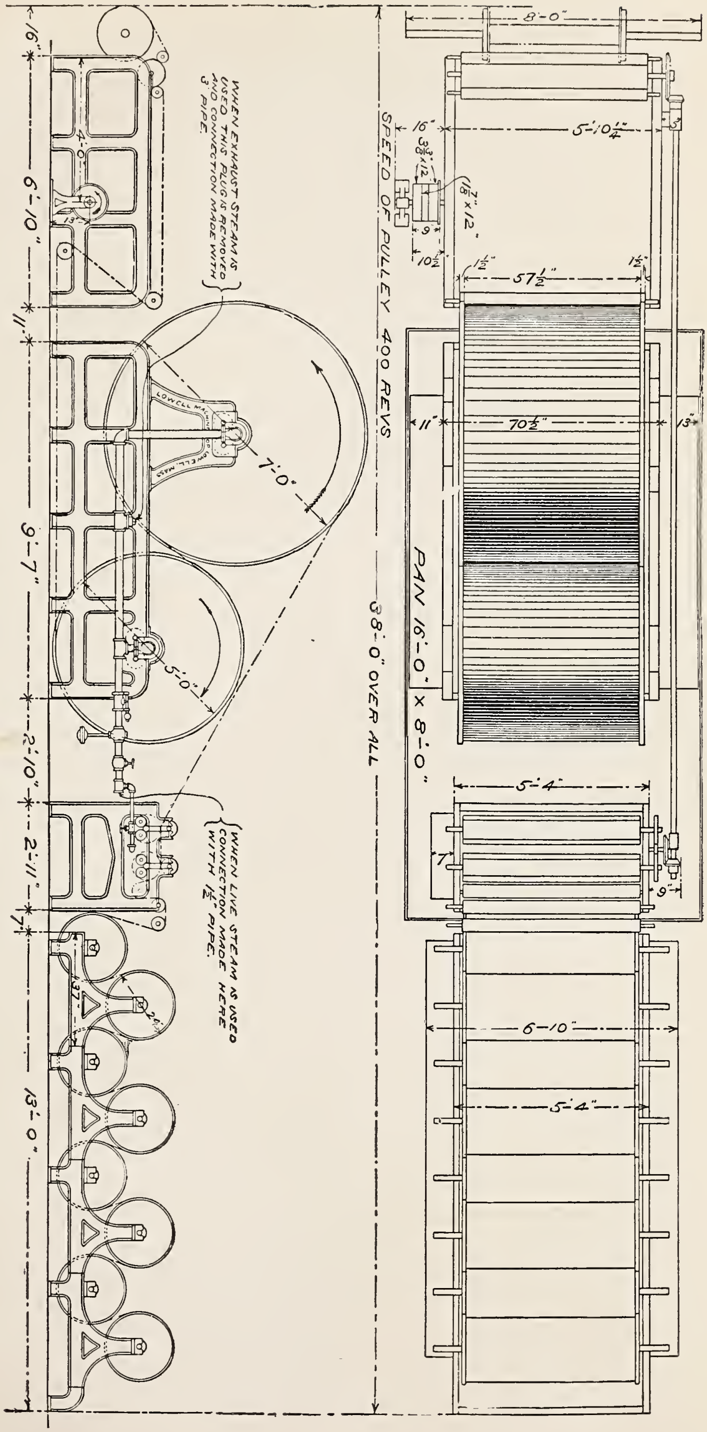
The size for finishing the cloth is handled in a little different way. The cloth is passed in some cases into the hot size or finish, then between squeeze rolls and over dry cans, or else instead of passing the cloth into the size the lower roll of the sizing machine dips in the hot size and carries more or less of it up on its surface as it rapidly revolves. Either the back or the face of the cloth is brought in contact with this coated roll before it comes in contact with the squeeze roll over it, and thus the surface of the cloth is more or less coated with the size. Different modifications are necessary in order to produce the various effects required for different styles of finish. After being sized, the cloth is slightly moistened or sprayed with water, and then put through the different machines, calenders, presses, beetles, stenters, etc., for stiffening, softening, lustering, dulling, watering, embossing, or producing any other effect which is considered essential to the proper appearance of the finished fabric. It will be seen that there is an opportunity for utilizing the various properties of all the gums and starches and also the various chemicals which may react on them in order to produce these different results.

Of the several uses for potato starch mentioned above, by far the most important is for the sizing of warps. Indian-corn starch is used altogether for laundry purposes, and, so far as I know, very little potato starch is used for finishing cloth. In spite of the higher price of potato starch, and it ranges generally from 50 to 100 per cent higher than indian-corn starch, and also in spite of the fact that, weight for weight indian-corn starch will give a stiffer paste than potato starch, it is claimed for the latter that it is better for sizing purposes, especially for the sizing of fine yarns. Potato starch gives a more elastic size at the same time is thinner and more penetrating. Indian-corn starch size lies more on the surface of the fiber than the potato starch, so that a given number of threads sized with the indian-corn starch will take up more room when laid side by side than the same number sized with potato starch. Thus a cloth sized with indian-corn starch, then woven and the size washed out, will give a more open fabric than if it had been sized with potato, provided, of course, that the yarn has been woven as close together as possible. This is an old claim which it seems would be a proper subject of scientific investigation before it is accepted as fact.

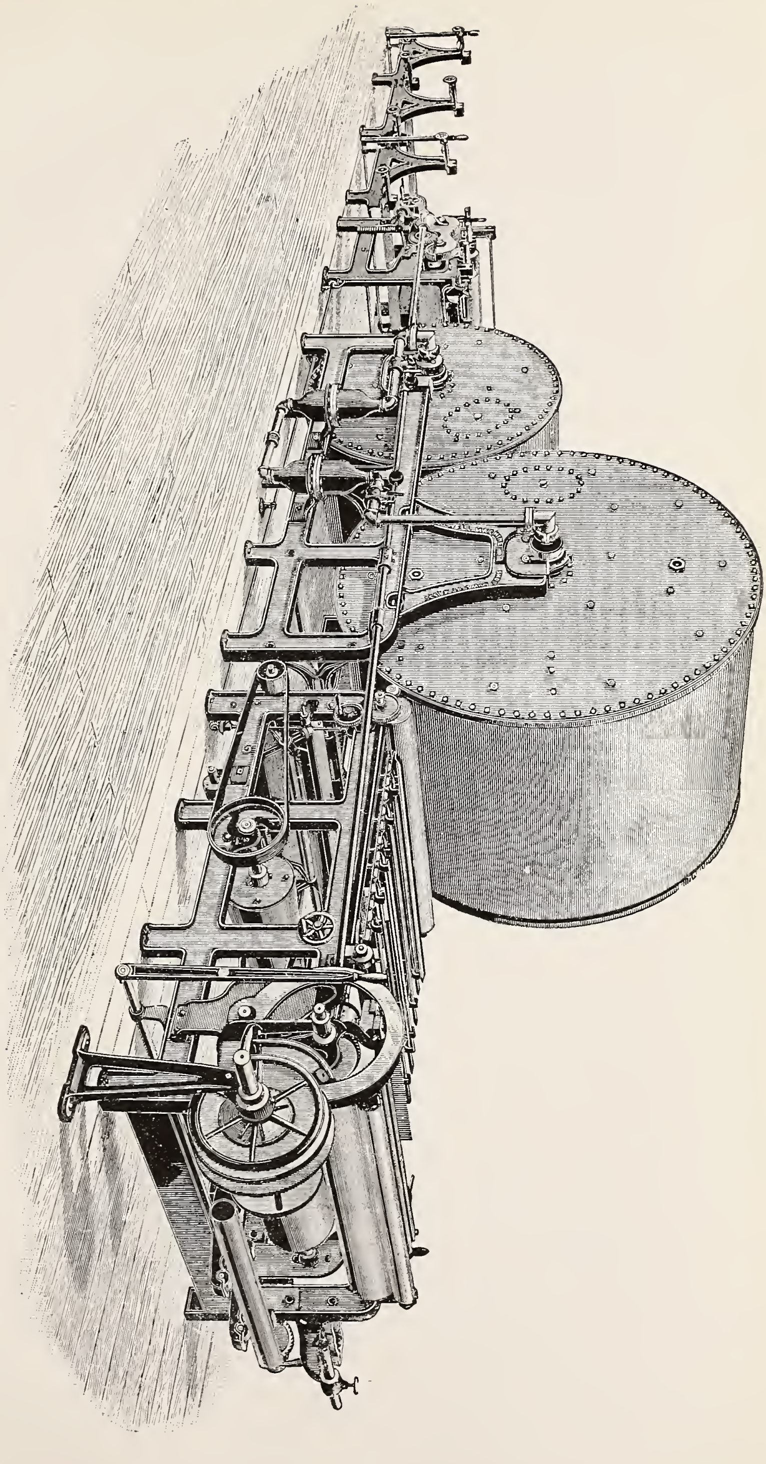
The fact that the potato size penetrates more thoroughly and is more elastic than the indian-corn size is the reason why the former dusts off less in weaving than the corn size.

Twenty years ago there was not very much difference in the price of indian-corn and potato starch. Within the last five years the price of the former has ranged between 2 cents and $1\frac{3}{8}$ cents for the manufacturers' grade, while the price of the latter has averaged between 3 and 4 cents. Of course there are extreme fluctuations outside of these prices, as in the case of potato starch two years ago, when the price dropped to $1\frac{7}{8}$ cents. This is not likely to occur again.

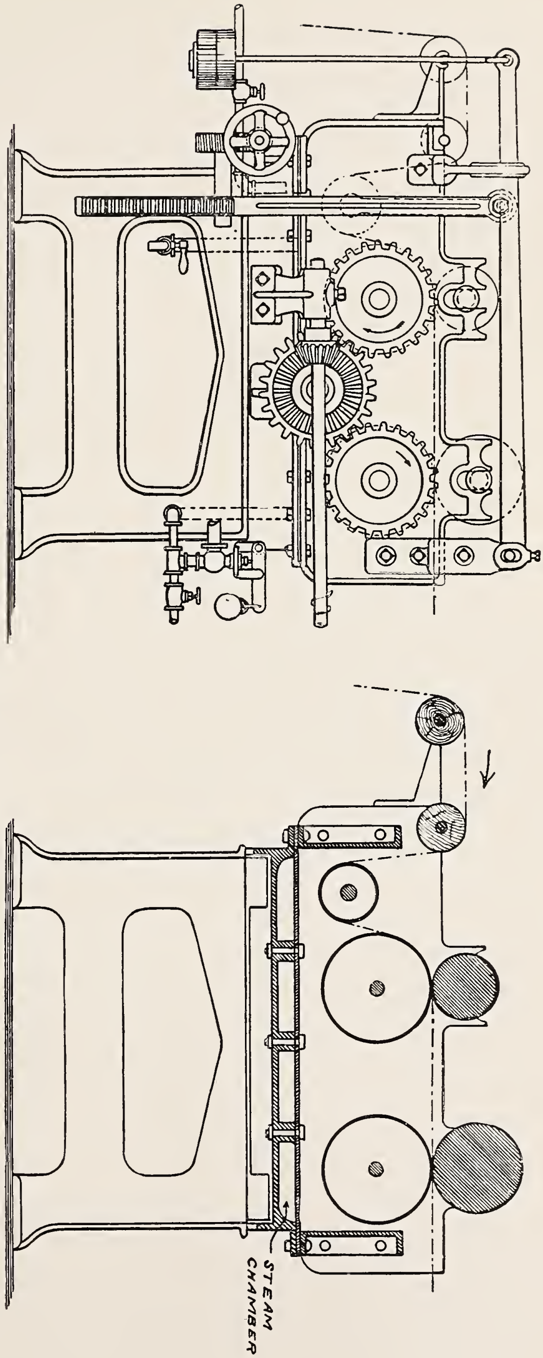
There are one or two preparations of potato as well as of indian-corn starch which are coming into use as ingredients of sizes and finishes, used in connection with the ordinary starch. One of the oldest of these is the exceedingly thick pasty preparation formed by kneading starch with strong caustic soda or potash. Sometimes the alkali is partially neutralized without losing any of its thickening properties



CYLINDER SLASHER (PLAN, AND SECTIONAL VIEW).



CYLINDER SLASHER (GENERAL VIEW).



STEAM-JACKETED SIZE VAT.

Another product is formed by heating starch with a solution of zinc or magnesium chlorid, with or without pressure, by which an important change is effected in the properties of the starch paste. They are sold in the paste or dry form to be used in connection with ordinary starch size.

POTATO STARCH AS A SOURCE OF DEXTRIN.

In Europe large quantities of potato starch are used for the manufacture of dextrin, or British gum, as it is often called. In the process of manufacture the starch is submitted to a high temperature, preferably in contact with the diluted vapors of nitric acid. The action of the heat, in connection with the slight quantity of nitric acid present, is sufficient to convert the starch into dextrin, in which form it is used for various kinds of mucilage, as, for instance, applied to postage and other stamps, the sealing edge of envelopes, etc. The manufacture of dextrin or gum of this kind is an important branch of the industries connected with starch.

SIZING MACHINES AND PROCESSES.

A type of the machine employed for yarn sizing is shown in Plate IV, which gives a sectional view of the various parts of the machine. A general view of the same apparatus is shown in Plate V.

The operation is conducted as follows: When the yarn leaves the spinning frame, it is wound on little tubes, and the yarn that is intended for the warp is then wound off onto spools. From 300 to 400 of the spools are placed in a frame, the end of the thread on each spool is passed through a wire loop, the loops being arranged close together side by side so that the yarn comes from them in a flat sheet, and it is then wound onto a wooden roll a little wider than the cloth to be woven. The yarn is now ready for the slasher, which is the ordinary name given to the sizing machine. The exact arrangement of the sizing vat is shown in Plate VI. The small brass immersion roll in the tank at the left carries the yarn down under the boiling size, thence the yarn passes between the hollow copper size roll and the heavy solid iron roll on top of it. The object of this process is to press the size thoroughly into the fiber of the yarn and to remove any excess.

Inasmuch as an unbleached yarn is rather difficult to wet thoroughly with such a thick liquid as size, it is necessary that every yarn thread should be passed through a second pair of sizing rolls shown on the right of the figure. The bottom roll dips into the size so as to carry it up to the yarn. The squeezed yarn then passes to the top of the large dry can, which is not shown in the figure, and generally over a second can where it is thoroughly dried. It then passes to the winding head where the threads are separated and wound off on a single roll at the extreme right of the machine.

The foregoing description and accompanying illustrations give a general idea of how the size is applied to the yarn, but it is not the object here to go into greater detail. The processes of drying on the cans or on stenters, the spraying or damping, and the final finishing or calendering are complicated operations pertaining especially to the technique of the textile industry and not particularly to the use of starch for the sizing material.

THE USE OF POTATOES FOR THE MANUFACTURE OF ALCOHOL.

In Europe nearly all the starch which is used for commercial and technical purposes and a large part of the alcohol for the same purposes are produced directly from potatoes. A brief summary of the process of making alcohol from potatoes will prove of interest in this connection.

WASHING THE POTATOES.

Various forms of machines are used for washing the potatoes, the general principles of which are the same as those of the machine already described and illustrated in fig. 3.

STEAMING THE POTATOES.

After the potatoes are free from dirt, they are taken, by means of the elevator, to the steaming machine. The steaming machine consists of a vessel of a size appropriate to the magnitude of the factory, and capable of withstanding several atmospheres of steam pressure, with a stirring apparatus, by means of which the potato paste, produced in the process of steaming, can be uniformly mixed. If very thick paste be required, after the potatoes are placed in motion the manhole is closed; steam is introduced slowly until the walls of the apparatus and the potatoes become hot. By then opening the cock at the bottom of the apparatus, the water of condensation which is produced is allowed to escape. When the potatoes begin to become soft under the influence of the steam, the stopcock is closed and the steam is continued with the stirring until the whole mass is reduced to a homogeneous paste. The water contained in the potatoes furnishes an abundant supply for the formation of the paste. The pressure of the steam is usually from 2½ to 3½ atmospheres, producing a temperature of from 130 to 135° C. At this temperature the starch granules are disorganized and by the mechanical motion of the stirrer are reduced to a pasty, semifluid condition. Usually about three hours are employed in this process.

THE CONVERSION OF THE STARCH INTO SUGAR.

Before fermentation can set in, it is necessary that the starch of the steamed potatoes be reduced to sugar capable of yielding to the action of the ferment germs. To do this, after the steaming is complete, a vacuum pump is attached to the steaming apparatus and under the influence of the vacuum the pasty mass of starch, which is kept in motion, is rapidly cooled, until the temperature reaches about 65° C. At this stage, a proper proportion of malt cream—that is, malt mixed with a sufficient quantity of water to form a thick semisirupy liquid—is introduced into the mass and evenly distributed therein by means of the stirrers. The diastase of the malt acts at once upon the starch and converts it into maltose, a sugar which is easily acted upon by the ferments for the production of alcohol. As the starch paste is converted into maltose it becomes thinner and thinner until at the end of the operation it is in a liquid condition. The quantity of water which is employed is such that the percentage of sugar in the mash thus formed varies from 16 to 24. The saccharization of the starch paste under the influence of the malt is accomplished in a very short time and the liquid contents of the steaming apparatus are then ready for transference to the fermentation vats.

FERMENTATION.

Fermentation takes place under the influence of yeast in exactly the same way as fermentation of indian-corn starch is produced in the manufacture of whisky and the fermentation of barley and other cereals in the manufacture of beer. It is not proposed here to go into the details of the fermentation process, which, of course, varies with the environment. The object is to conduct the fermentation at such a temperature and in such a way as to secure the largest possible quantity of alcohol from the sugar present.

DISTILLATION.

After the fermentation is complete, the alcoholic mass is subjected to distillation in the usual way. Various forms of stills are employed, but the most convenient one is a combination of the old-fashioned still and the rectifiers' still. By the operation of one of these stills a high degree of alcohol, 95 to 96 per cent, of great purity, is produced at the first distillation. If the object be simply to procure an alcohol in the crude state, the distillation is carried on in an intermittent still and the alcoholic product, which is quite impure, is afterwards subjected to rectification.

CHEMICAL COMPOSITION OF MAINE POTATOES.

Attention has already been called to the fact that the potatoes used for the manufacture of starch in Maine are usually the small, imperfect, or injured potatoes, which are separated from the better quality before sending to market, or they are the potatoes which by reason of immaturity are not fit for table use. It is more profitable for the growers of potatoes to sell their product, when ready for the market, directly to the grocers or to the consumers than to the starch makers.

Any data, therefore, based upon the imperfect, injured, or immature potatoes which are found in the starch factories would not be a fair criterion of the potato itself as grown in Maine.

Through the courtesy of Dr. C. D. Woods, director of the agricultural experiment station at Orono, Me., samples have been received of Maine-grown potatoes, which are fairly representative of the potatoes of the different varieties grown in that State. These samples were submitted to a careful analysis to determine their content of starch.

For our present purpose it was deemed sufficient to determine the moisture, starch, fiber, protein, ash, and specific gravity.

The starch was determined in three different ways, namely, from the specific gravity of the potato, by washing the starch of the grated potato through silk bolting cloth, and by the official method[1] of determining starch in potatoes. The data obtained from the first and second methods were very unsatisfactory, varying somewhat more than 5 per cent over the numbers obtained by the official method.

The numbers given in the following table are those obtained from the official method alone.[2]

Analyses of potatoes grown in 1898, the results calculated to water content at time of sampling.

Variety.	Serial No.	Maine No.	Moisture.	Starch.	Fiber.	Protein (nitrogen × 6.25.)	Ash.	Total.	Specific gravity.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Hebron	17538	3036	79.72	16.94	0.90	2.12	0.76	100.44	1.0604
Hebron	17539	3037	78.13	18.59	0.72	2.06	0.78	100.28	1.0795
White Elephant	17540	3038	76.81	19.96	0.84	2.19	0.99	100.79	1.0867
White Elephant	17541	3039	76.92	20.38	0.90	2.31	0.87	101.38	1.0742
White Elephant	17544	3044	78.74	15.96	0.64	2.25	0.92	98.51	1.0803
White Elephant	17545	3045	75.21	19.31	0.61	2.12	0.83	98.02	1.1058
White Elephant	17546	3046	75.88	18.81	0.56	2.25	0.96	98.46	1.0921
White Elephant	17547	3047	77.44	18.12	0.63	2.06	0.88	99.13	1.0906
White Elephant	17548	3050	75.56	18.14	0.56	1.81	1.04	97.11	1.1129
White Elephant	17549	3051	78.13	18.62	0.63	1.75	0.98	100.11	1.0881
Delaware	17542	3040	76.02	19.20	0.61	2.06	1.01	98.90	1.0852
Delaware	17543	3041	76.93	18.63	0.61	2.19	0.94	99.30	1.0904
Delaware	17550	3052	75.72	18.63	0.55	2.31	0.95	98.16	1.0745
Delaware	17551	3053	77.64	16.26	0.61	2.56	0.91	97.98	1.1120
Carmen	17552	3054	76.87	18.03	0.66	2.06	0.90	98.52	1.0967
Carmen	17553	3055	76.57	17.07	0.59	2.38	0.76	97.37	1.0804

From an inspection of the figures of the above table, it is evident that the starch content of some of the samples is quite low. In regard to these Dr. Woods remarks, in a letter dated April 25, 1899: "As you probably remember, potatoes rarely mature in Aroostook County naturally. The tops are either killed by blight or by frost. In accordance with my experience the potatoes there grown are more or less inclined to be watery. This would seem to imply that the maximum starch has not been developed."

[1] See Bulletin No. 46, Revised, of the Division of Chemistry, p. 25.

[2] Analyses by W. H. Krug and T. C. Trescot (nitrogen).

DESCRIPTION OF THE POTATO SAMPLES.

The following description of the potatoes, the soils in which they were grown, and the methods of culture and spraying employed have been kindly furnished by Director C. D. Woods, of the Maine station. The numbers of the samples are those given at the Maine station:

No. 3036, Beauty of Hebron.—Grown by C. H. Richardson, Fort Fairfield; sample was taken from a field of 8 acres which had been in pasture since being cleared until 1896. In 1896 it bore a heavy crop of potatoes without any rust; in 1897 it was again planted to potatoes, with a light yield and an early rust. The yield in 1896 was about 100 barrels per acre, and in 1897 about 50 barrels. The soil is light-red loam, and like most land in that vicinity is on a shell-like lime-rock ledge. The field was plowed in the fall of 1897, and harrowed three times in the spring with a spring-toothed harrow. It was planted with a planter and hoed with a horse hoe. The field had received no manure until in 1896; in that year, in 1897, and in 1898, it received about 500 pounds of complete fertilizer per acre. In 1898 the crop was planted May 10 and harvested between September 1 and 20.

The crop was sprayed twice with Bordeaux mixture, July 30 and August 9, but it was too late to save the plants from the blight. The yield was about 50 barrels of merchantable potatoes and 15 barrels of small ones per acre.

No. 3037, Beauty of Hebron.—These potatoes were taken from a field adjoining that from which No. 3036 was taken. The field was plowed for the first time in the fall of 1897, and the crop was grown on the sod without the addition of any fertilizing materials.

Nos. 3038 and 3039, White Elephant, and 3040 and 3041, Delaware.—These samples were from T. B. Bradford, Golden Ridge, Sherman, Maine. The land had a slope to the north; had been in grass until October, 1897, when it was plowed. The soil was dark, inclined to be wet, and was not underdrained. The subsoil was gravelly. It received about ten 2-horse loads of barn manure, broadcast over the field and about 500 pounds of fertilizer per acre; the fertilizer was applied in the drill. The field was planted June 1 and harvested September 28. The whole field was sprayed three times with Bordeaux mixture by the use of the Aspinwall sprayer; in addition to this, sample No. 3038 was sprayed more with a knapsack sprayer. At the time that had been sprayed five times, the others were killed by rust. There were 45 barrels of merchantable potatoes and 75 barrels of small potatoes per acre. All of the potatoes rotted very badly, and the decay began before any of the leaves were killed.

Nos. 3044 and 3045, White Elephant.—These samples were received without the name of the sender. No. 3044 was not sprayed, and No. 3045 was sprayed with Bordeaux mixture.

Nos. 3046 and 3047, White Elephant.—These were grown by R. S. Hoyt, of Fort Fairfield. The field has a slope to the northeast, and was in pasture previous to 1896. In 1897 a crop of potatoes was grown with the addition of 300 pounds of fertilizer. The yield was about 60 barrels. The field was plowed again in October, 1897, harrowed May 20, 1898, planted May 24, and harvested September 21. Four hundred pounds of complete fertilizer were used, applied in the drill. The part from which No. 3046 was taken was sprayed twice, and 3047 was not sprayed. The yield was 65 barrels of merchantable potatoes and 25 barrels of small potatoes per acre.

Nos. 3050 and 3051, White Elephant.—Grown by Powers Brothers, of Caribou. The field bore potatoes in 1895; was seeded to oats in 1896, and grew a crop of red clover in 1897. The soil is a medium light clay loam with a gravelly subsoil. The field was plowed in October, 1897, and harrowed in the spring. Four hundred pounds commercial fertilizer were applied in the drill, and the piece was planted May 15–19, and harvested September 20–25. The field was sprayed three times, but finally succumbed to the blight. The yield was 60 barrels of merchantable potatoes and 13 barrels of small ones per acre. No. 3051 was from an unsprayed portion of the field.

Nos. 3052 and 3053, Delawares.—The name of the sender and the culture is not known, except that 3052 was sprayed with Bordeaux mixture and 3053 was unsprayed.

Nos. 3054 and 3055, Carmen.—These were from the same person as 3052 and 3053. No. 3054 was sprayed with Bordeaux mixture, and 3055 was unsprayed.

For the purpose of comparison it may be of interest to give the table showing the mean composition of potatoes, as given by König, Lintner, and E. Wolff.

Table showing mean composition of potatoes.

Constituents.	König.	Lintner.	E. Wolff.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	75.48	76.0	75.0
Protein (N. × 6.25)	1.95	2.1	2.1
Fat (ether extract)	.15	.2	.2
Starch	20.69 (Starch and other nonnitrogenous materials together)	18.7	20.7 (Starch and other nonnitrogenous materials together)
Other nonnitrogenous materials		1.0	
Fiber	.75	.8	1.1
Ash	.98	1.2	[illegible]

A careful analysis made by Morgen of 38 different varieties of potatoes gave the following results:

Table showing mean composition of potatoes.

Specific gravity and constituents.	Maximum.	Minimum.	Mean.
Specific gravity of the potatoes	1.134	1.084	1.106
Specific gravity of the juice	1.0368	1.0216	1.0263
	Per cent.	*Per cent.*	*Per cent.*
Dry substance	30.39	20.33	25.57
Moisture	79.67	69.61	74.43
Juice	72.01	52.42	61.02
Substances soluble in water	5.17	2.66	3.21
Total nitrogen	.489	.229	.324
Soluble nitrogen	.446	.202	.270
Insoluble nitrogen	.100	.009	.056
Proteid nitrogen	.225	.099	.141
Amid nitrogen	.219	.073	.118
Other forms of nitrogen	-.033	.002	.012
Total carbohydrates calculated as sugar	27.283	16.730	22.237
Total carbohydrates calculated as starch	24.555	15.057	20.013
Starch	24.260	14.532	16.615
Sugar	1.080	.073	.267
Dextrin	.276	.049	.164
Total ash	1.208	.650	1.076
Soluble ash	.948	.506	.730
Insoluble ash	.477	.079	.262

The influence of nitrogen on the starch content of potatoes is shown in the following table, taken from Maercker's work on the manufacture of alcohol from potatoes:

Table showing influence of nitrogen on starch content of potatoes.

Variety of potato.	Fertilized.					
	Without nitrogen.			With nitrogen.		
	Starch.	Yield of tubers per hectare.	Yield of starch per hectare.	Starch.	Yield of tubers per hectare.	Yield of starch per hectare.
	Per cent.	*Kilos.*	*Kilos.*	*Per cent.*	*Kilos.*	*Kilos.*
Seed	18.01	20,900	3,780	18.17	24,870	4,507
Champion	21.33	19,510	4,152	21.48	24,470	5,233
Imperator	19.00	22,560	4,235	18.70	26,830	5,007
Magnum bonum	18.41	19,170	3,522	18.07	22,510	4,057
Aurelie	19.47	18,950	3,653	19.75	23,550	4,609
Reichskanzler	22.78	14,300	3,236	22.61	17,250	3,875
Juno	19.33	17,590	3,422	19.92	20,900	4,199
Amaranth	22.47	16,180	3,619	22.84	18,310	4,188
Charlotte	19.42	17,041	3,305	19.67	20,774	4,081
Gelbfleischige Zwiebel	19.97	19,888	3,946	19.91	21,772	4,323
Daberache	21.82	17,377	3,778	21.80	20,313	4,399
Weissfleischige Zwiebel	20.51	16,877	3,442	20.58	19,501	3,936
Schneerose	18.84	19,653	3,724	18.66	22,343	4,186
Nassengrunder	19.08	19,701	3,725	22.12	21,889	4,813
Gelbe Rose	21.09	16,847	3,547	20.60	20,177	4,129
Hortensie	17.72	22,416	3,907	17.45	26,381	4,532
Richters lange weisse	19.37	22,134	4,267	19.19	24,490	4,664
Rosalie	18.27	19,866	3,557	18.25	22,186	4,003
Achilles	21.02	18,886	3,962	20.93	20,913	4,376
(?) Alcohol	16.47	16,270	2,673	16.31	20,339	3,327
Average	19.77	18,805	3,673	19.85	21,998	4,322

It is evident that liberal applications of nitrogenous fertilizers increase the percentage of starch in the tuber and the yield per hectare.

It will be observed in the above analyses that the potatoes of foreign origin have a somewhat higher content of starch than the potatoes grown in Maine. In explanation of this fact it is stated that for many years systematic efforts have been made in Germany and in other parts of Europe to produce a potato rich in starch, not only for starch making, but also for the manufacture of alcohol, since in Europe potatoes are almost the sole source of commercial starch and commercial alcohol. These potatoes are not the best for table use, however. The potatoes grown in Maine, although possessing a lower content of starch are much superior in palatability for domestic consumption. The increased content of starch, therefore, in foreign potatoes does not by any means indicate that the Maine-grown potatoes are inferior articles, but that the foreign-grown potato has been developed preeminently into a starch-producing vegetable.

ASH CONSTITUENTS OF MAINE-GROWN POTATOES.

For the purpose of determining the extent of the mineral drain upon the soil by the potatoes grown in Maine, a comparative analysis of the ash of a number of the samples from Maine, given in the table on page 28, was made. The analytical data are as follows:[1]

Analyses of the ash of potatoes.

Serial No.	Maine No.	Potash.	Soda.	Lime.	Magnesia.	Phosphoric acid.	Sulphuric acid.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
17545	3045	55.13	1.70	1.01	3.85	15.78	6.92
17547	3047	56.16	1.62	1.38	3.93	14.50	5.98
17548	3050	56.43	1.70	1.29	3.76	15.00	6.38
17549	3051	57.30	2.15	1.05	3.57	13.33	5.56

From these analyses it is seen that the principal mineral ingredients of potato ash are potash and phosphoric acid. The quantity of lime is remarkably small in comparison with the magnesia present. Sulphates are present in considerable quantities. Sand, carbon, silica, carbonic acid, and chlorin are not considered in the above results, which represent the constitution of the pure ash—that is, the ash free of all impurities save carbonic acid. The difference between the sum of the percentages in each case and 100 represents the carbonic acid and errors of analyses.

MICROSCOPIC APPEARANCE OF POTATO STARCH.

The starch grains of the potato are among the largest of the starch family, but are very variable in size. They vary from 0.05 to 0.12 millimeter in length, are oval in shape—sometimes almost round in the smaller granules. The oval forms have a breadth practically one-half of their length. In Pl. VII, fig. 1, are shown starch granules from a potato grown in Aroostook County, Me., as they appear under the microscope. The drawings were made from the microscope by a camera lucida. The magnification of the granules is 300 diameters. The appearance of the field would indicate that the smaller granules are not fully grown or mature—that is, that they represent the last ones formed in the growth of the potato, while the larger ones represent the granules which were first formed, and which have grown to full size. The larger granules also have the appearance of having grown by accretion, since they are marked by well-defined layers, which are not shown in the smaller ones. These layers are shown by rings, which seem to be concentric near one end of the oval-shaped granules, and this origin of concentric rings is called the hilum. The hilum sometimes appears as a shadowy depression. With polarized light the structure of the starch granules is more clearly brought out, as is shown in Pl. VII, fig. 2, in which the granules are magnified the same number of diameters as in the preceding figure. Under the crossed nicols with polarized light a well-defined dark cross is shown

[1] Analyses by C. C. Moore.

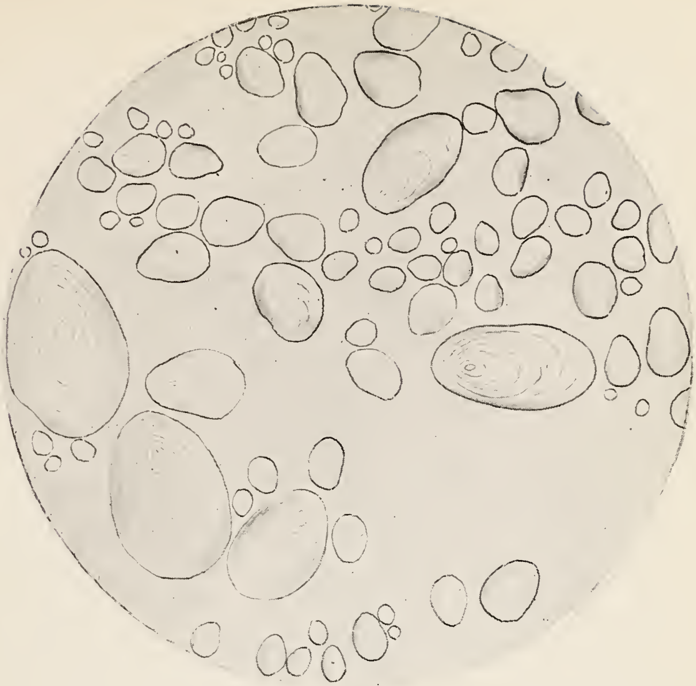


FIG. 1.—POTATO STARCH. (× 300.)

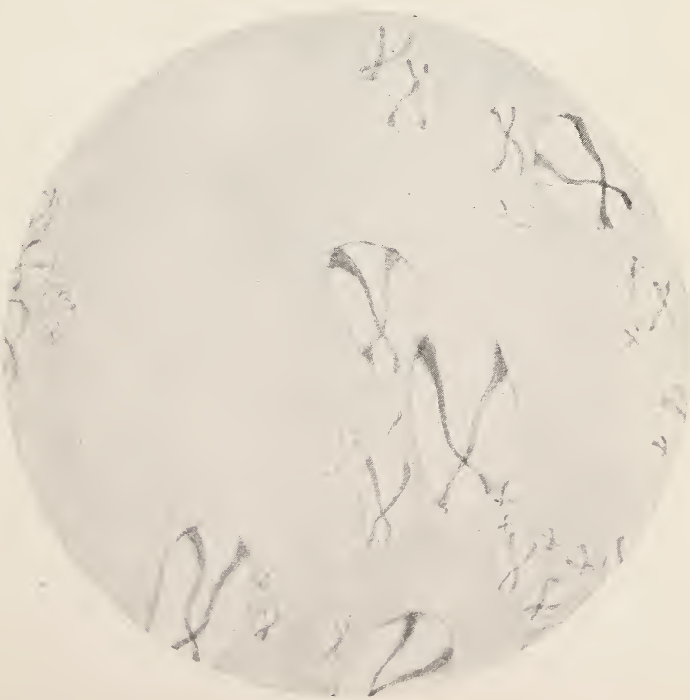


FIG. 2.—POTATO STARCH, VIEWED WITH POLARIZED LIGHT. (× 300.)

on all the granules, even the smallest. This indicates that the starch particles are joined together according to some crystallographic law. By revolving one of the nicols the crosses change from dark to light. Viewed with a selenite plate the starch granules show rays of colors which are characteristic.

DESICCATION OF POTATOES.

In order that potatoes may be kept for a long time and used in localities where great variations of temperature exist, a process of desiccation or evaporation has been applied to them with great success.

Practically, in the desiccation of potatoes, the same principles are observed as in the desiccation of fruits. In the potato, however, the material to be dealt with is quite different from that found in fruit. In apples and other fruits, which are usually subjected to the drying process, very little starch is found, the prevalent carbohydrate being a sugar of some description. In the potato, on the contrary, the principal part of the solid material is starch. It is therefore highly necessary in the process of evaporation to conduct the operation in such a manner as to avoid the breaking or swelling of the starch granules, under the influence of moisture and heat. For this reason the process of evaporation should be begun at a very low temperature. As the water which the potato contains is driven off, the temperature can be gradually raised, so that toward the end of the operation it may attain even the boiling point of water without any great danger.

By proceeding in this manner, the process of evaporation is completed without causing the starch grains to swell or to become unusually soft.

Before the evaporation begins, the potatoes are submitted to the fumes of burning sulphur to protect them from discoloration. The heat of the evaporation finally expels all of the sulphur fumes, so that no objection can be raised to the consumption of this evaporated article by reason of the presence of sulphurous or even sulphuric acid, only traces of which are formed by the sulphurous acid employed.

It is not probable that the evaporated potatoes could be used for the manufacture of starch, for although the starch granules have not been reduced to the form of a paste by the process of evaporation, nevertheless the starch has been more or less changed in its nature by exposure to a high temperature, so that it partakes more or less of the character of amylodextrin.

For nutritive purposes, however, the starch in the desiccated article is fully as valuable as in the original material, if not more so. Since the desiccated particles contain all of the nutritious matter originally present in the potato, together with the cellulose, both digestible and indigestible, it is evident that the nutritive value of the material is scarcely inferior in any way to that of the potato in the original state.

Thus, in the process of desiccation, the potato is reduced to a form in which it can be easily preserved both in extreme heat and in extreme cold, while its nutritive properties are not impaired to any appreciable extent. The desiccated potato, therefore, forms an excellent article for transportation to arctic or tropic regions, or for the nourishment of our soldiers and sailors when distant from supplies of fresh vegetables.

The magnitude of the industry of the desiccation of potatoes in the United States is not very great, but it is a business which promises well for the future, in the preparation of certain forms of potato products suitable for special purposes.

MANUFACTURE OF STARCH FROM CASSAVA.

In Bulletin No. 44 of the Division of Chemistry is found a description of the sweet cassava, with remarks on its culture, properties, and uses. This bulletin is out of print, and it is therefore advisable, in treating of the subject of the manufacture of starch from cassava, to show the nature of its contents. Cassava grows in this country in the southern peninsula of Florida, and well up into the frost belt, and is also found in other of the extreme southern portions of the United States. From a careful study of the climatic conditions under which the plant flourishes, it is safe to assume that it may also be grown with success in southern Alabama, Mississippi, Louisiana, Texas, Arizona, and southern California.

The name "cassava" should properly apply only to the purified starch derived from the roots of the plant, but it has passed into general use to designate the plant itself. I am informed by the Division of Botany that the plant is known by various names, as, for instance, *Janipha manihot*, *Manihot utilissima*, *Jatropha manihot*, *Manihot aïpi*, *Manihot lœflingii*, and *Manihot palmata*. One of its common names is manioc plant. The fleshy root of this plant yields the greatest portion of the daily food of the natives of many portions of tropical America, and one of its forms of starch is imported largely into this country as tapioca.[1] It is a woody or shrubby plant, growing from fleshy, tuberous roots, the stems being smooth, with nodules where the leaves grow.

There is properly only one variety of the plant growing in Florida, while that variety which grows in the Tropics contains so much hydrocyanic acid as to render it poisonous. The variety grown in the subtropical region of Florida, however, contains only a small quantity of hydrocyanic acid, and is therefore commonly known as sweet cassava. Some of the growers of the plant in Florida claim that two

[1] Three forms of tapioca are recognized in commerce, pearl tapioca, flake tapioca, and tapioca flour. The latter would be more appropriately called tapioca starch or cassava starch.

varieties grow in the State, one of which is poisonous on account of the large amount of hydrocyanic acid which it contains, and the other nonpoisonous, as it contains only a little hydrocyanic acid. It is quite probable, however, that after the poisonous variety has grown for a long while in a subtropical climate it would lose largely its poisonous properties. The leaves of the poisonous variety in the Tropics usually have seven branches, palmately divided. The leaves of the sweet variety are usually only five-parted. The botanists clearly recognize two distinct varieties. For instance, in the Treasury of Botany (p. 718) the following remarks are made:

> It is quite clear that while the root of one is bitter and a virulent poison that of the other is sweet and wholesome, and is commonly eaten cooked as a vegetable. Both of them, especially the bitter, are most extensively cultivated over the greater part of tropical America and yield an abundance of wholesome and nutritious food, the poison of the bitter kind being got rid of during the process of preparation it undergoes. The poisonous expressed juice, if allowed to settle, deposits a large quantity of starch known as Brazilian arrowroot or tapioca meal, from which the tapioca of the shops is prepared by simply torrefying the moist starch upon hot plates, the heat causing the starch grains to swell and burst and become agglutinated together. A sauce called cassareep, used for flavoring soups and other dishes, particularly the West Indian dish known as pepper pot, is also prepared from this juice by concentrating and rendering it harmless by boiling. Another of the products of cassava is an intoxicating beverage called piwarrie, but the manner of preparing it is not calculated to render it tempting to Europeans. It is made by the women, who chew cassava cakes and throw the masticated materials into a wooden bowl, where it is allowed to ferment for some days and then boiled. It is said to have an agreeable taste.

CASSAVA AS AN ARTICLE OF FOOD.

The sweet cassava as grown in Florida is a common article of diet, as well as the source of the domestic starch used over large portions of the peninsula. The roots of the cassava are grated and used directly as human food, and they are also fed to cattle, pigs, mules, and horses, with very happy effects, being a food which is greatly relished. Cassava flour is prepared as a domestic product in many parts of Florida and other localities where the cassava is grown. In the preparation of cassava flour the root is peeled, chopped into thin slices or grated, spread in the sun for two or three days until sufficiently dry, and then ground into a fine powder. In this state it is used for making a kind of bread for puddings and for other culinary purposes. In the making of puddings the addition of milk, eggs, sugar, etc., to suit the taste, is recommended. As a substitute for wheat flour in making bread, the cassava flour is of course inferior in general nutritive and culinary properties. It contains an excessive amount of carbohydrates, and is therefore not as well balanced a ration as bread which is made from wheat. For instance, in ordinary wheat flour the nitrogenous bodies vary from 8 to 14 per cent, while in cassava flour they rarely reach as much as 2 per cent. The chemical composition of the cassava roots and of the cassava flour, as determined in this laboratory, is shown in the following tables:

Composition of cassava root (dry matter).

Serial number	5547
	Per cent.
Ash	1.94
Petroleum ether extract (fat)	1.27
Ether extract (resins, organic acids, etc.)	.74
Alcohol extract (amids, sugars, glucosids, etc)	17.43
Crude fiber	4.03
Starch	71.85
Protein (nitrogen × 6.25)	3.47
	100.73

Composition of cassava flour.

Serial numbers	5922	5923
	Per cent.	Per cent.
Moisture	10.56	11.86
Ash	1.86	1.13
Petroleum ether extract (fat)	1.50	.86
Ether extract (resins and organic acids)	.64	.43
Alcohol extract (amids, sugars, glucosids)	13.69	4.50
Dextrin, gum, etc., by difference	2.85	5.63
Crude fiber	2.96	4.15
Protein (nitrogen × 6.25)	1.31	1.31
Starch	64.63	70.13

Most extraordinary statements have been made in regard to the yield of cassava per acre. Careful measurements, however, made under the direction of this Division, show that the magnitude of the crop is usually very much less than is stated in the reports which have been made. An average crop, under favorable conditions, may be placed at 5 tons of roots per acre. In many cases, however, the yield, where no fertilization is practiced and where the roots are grown upon sandy soil, is much less than this. In the statement above, showing the composition of the root, the analysis of a single sample of roots is given. In order to determine the composition of a more general sample, large quantities of roots were obtained from Florida and subjected to analysis, and the means obtained follow. In this case the roots were peeled in order to determine the composition of the material as it would be prepared for human food. In addition to the analysis of the peeled roots, the fiber remaining after the removal of the starch was also subjected to analysis, and likewise the bark which was removed from the root. In the case of the bark, however, the starch was not determined separately, but is included in the undetermined portion, forming, of course, a considerable portion thereof:

Composition of peelea root, and of the fiber and bark of the root.

Constituents.	Peeled root.		Fiber after removal of starch—dry.	Bark of root.	
	Fresh.	Dry.		Fresh.	Dry.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	61.30	....	....	61.30	....
Fat (ether extract)	.17	0.44	0.30	.66	1.70
Protein (nitrogen × 6.25)	.64	1.66	1.02	2.29	5.91
Starch (diastase extract inverted with HCl)	30.98	80.06	64.64	....	....
Fiber	.88	2.26	10.68	3.83	9.89
Ash	.51	1.31	1.42	2.02	5.23
Undetermined	5.52	14.27	21.94	29.90	77.27
Total	100.00	100.00	100.00	100.00	100.00

With the starch, in the analysis given above, is reckoned also the soluble carbohydrates, consisting almost exclusively of cane sugar, and of which, in an analysis of another portion of the dry substance, as high as 17 per cent was found. In the laboratory it is not difficult to prepare crystallized cane sugar from the aqueous extract of the fresh pulp. I have made such a preparation. The percentage of sugar in the plant, however, is too low to excite any reasonable hope of the preparation of this article on a commercial scale. The most promising way to save it is by conversion into glucose, as indicated in another place. The undetermined portion consists of the digestible fiber and carbohydrates of the pentose series. The pentosans in the fiber were determined by the furfurol process, as modified by Krug, and the amount in the air-dried material was found to be 3.92 per cent, and in the material after the removal of the starch 5.33 per cent.

The fresh root was found to contain 38.7 per cent of dry matter, being considerably more than was found in the fresh sample of the previous analysis. Of this 38.7 per cent, 30.98 consisted of starch and soluble carbohydrates.

Experiments were made to determine the yield of air-dry starch which could be obtained from the roots by laboratory work. Two sets of experiments were made. In the first set the roots were pulped on a Pellet rasp, used for preparing beet pulp for instantaneous diffusion. Twelve kilos of the unpeeled root were rasped in this way and the starch separated by washing through a sieve of bolting cloth. The washings and settlings were collected and dried in the ordinary method of starch manufacture. The yield of pure starch was 3,105 grams, equivalent to 25.9 per cent of the total weight of the root. The starch was almost absolutely pure, containing only a trace of nitrogenous matter. In the second experiment 10 kilos of the root were ground in a pulping machine, used for preparing green fodder for analysis. The pulp was much coarser than that produced by the Pellet rasp. Treated in the same way, the yield of air-dry starch was 2,360 grams, or 23.6 per cent. One of the striking points in connection with the work is that the residue after the extraction of the starch, consisting largely of fiber, contained still a large percentage of starch, showing that the process employed did not secure the whole of the starch from the pulp. The diameter of the starch granules is a little over 0.01 mm., being much smaller than the average of potato starch.

The relations of the mineral components of the cassava plant to the plant food in the soil, with the exception of nitrogen, are best studied from the ash. A large quantity of ash, therefore, was prepared from the peeled root and from the bark, and analyses of these samples were obtained. The data are given in the following table:

Analysis of the ash of the cassava root.

Constituents.	Peeled root.			Bark of root.		
	A.	B.	Mean.	A.	B.	Mean.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Carbon	0.30	0.31	0.31	0.79	0.77	0.78
Silica (soluble in solution of Na_2CO_3)	.97	.91	.94	10.53	11.36	10.94
Silica (insoluble in solution of Na_2CO_3)	7.15	7.15	7.15	52.99	52.16	52.58
Ferric oxid (Fe_2O_3)	.66	.66	.66	2.46	2.44	2.45
Calcium oxid (CaO)	10.63	10.64	10.64	6.58	6.65	6.62
Magnesium oxid (MgO)	7.36	7.35	7.35	3.31	3.33	3.32
Sodium oxid (NaO)	1.12	1.28	1.20	.84	1.05	.95
Potassium oxid (K_2O)	41.72	41.54	41.63	14.73	14.68	14.70
Phosphoric acid (P_2O_5)	15.58	15.59	15.58	2.44	2.46	2.45
Sulphuric acid (SO_3)	3.67	3.80	3.73	1.71	1.71	1.71
Carbonic acid (CO_2)	9.15	9.12	9.14	2.53	2.50	2.51
Chlorin (Cl)	2.76	2.75	2.75	1.41	1.42	1.41
Total	101.07	101.10	101.08	100.32	100.53	100.42
Oxygen equivalent to chlorin	.62	.62	.62	.31	.31	.31
Difference	100.45	100.48	100.46	100.01	100.22	100.11

From the above numbers it is seen that the ash of the peeled root is especially rich in potash, almost one-half of the total weight being composed of this substance. The potash is combined chiefly with carbonic and phosphoric acids. In the ash of the bark, as might be expected, silica is the predominant element, comprising more than half the total weight.

Assuming a yield of 5 tons of roots per acre, the weights of the important fertilizing materials removed by such a crop can be readily calculated from the data given.

Since the bark forms approximately 2.2 per cent of the entire root, the total crop would be made up of the following amounts of bark and peeled root which would contain the amounts of mineral matter given below:

Relative amounts of bark and peeled root in a crop of cassava, and amount of ash content.

Substance.	Pounds.	Pounds of ash.
Peeled root	9,780	49.88
Bark of root	220	4.44
Total	10,000	54.32

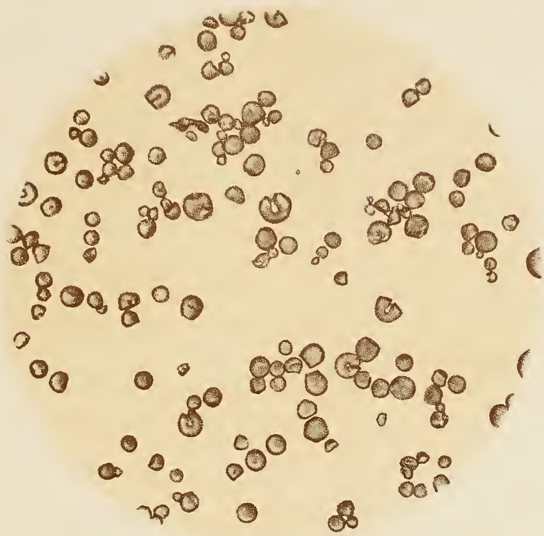


FIG. 1. STARCH GRANULES FROM CASSAVA. X 150

PLAIN ILLUMINATION.

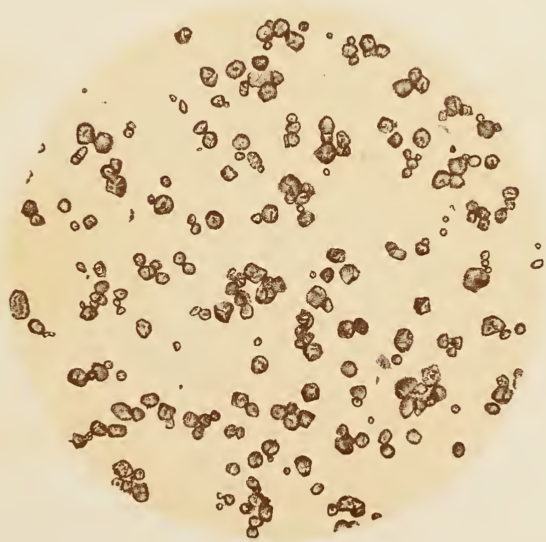


FIG. 2. STARCH GRANULES FROM MAIZE. X 150

PLAIN ILLUMINATION.

A Hoen & Co. Lithocaustic.

The most important mineral matters contained therein are shown in the following table:

Table showing mineral matter contained in ash of peeled root and bark.

Material.	Ash from peeled root (49.88 pounds).	Ash from bark (4.44 pounds).	Total ash from 5 tons (54.32 pounds.)
	Pounds.	*Pounds.*	*Pounds.*
Lime (CaO)	5.31	0.29	5.60
Magnesia (MgO)	3.67	.15	3.82
Potash (K_2O)	20.77	.65	21.42
Phosphoric acid (P_2O_5)	7.77	.11	7.88
Residue	12.56	3.24	15.60

The less valuable mineral plant foods—that is, those that are of so little note as to require no conservation or addition—amount to 15.60 pounds per acre and the more valuable to 32.72 pounds per acre.

MICROSCOPIC FORMS OF CASSAVA STARCH.

In Pl. VIII, fig. 1, is shown a photomicrograph of the starch granules derived from the cassava. The magnification is 150 diameters. In average size the starch granules of the cassava are much less than those of the potato, the mean diameter of the former being only .012 millimeter. In size the particles of cassava starch are practically the same as those of the maize starch, which for comparison are shown in Pl. VIII, fig. 2. The difference in outline, however, is very marked. Many of the maize particles have an irregular polygonal perimeter, while the cassava starch granules are mostly even and regular in outline. Among the cassava starch granules are found a few which have a very peculiar appearance, as if an elongated granule had been rolled together so that the ends almost joined. This is a peculiarity of form which, so far as I know, is not found in any other variety of starch. A few of the cassava particles of starch are also found irregular in outline, due to being placed close together in the substance of the root, but this number is by no means so great as that of similar granules appearing in maize starch. In general it may be said that the cassava starch resembles that of maize in its microscopic appearance more than any other common variety of starch.

METHODS OF CULTURE.

Cassava was grown for one year at the Department experiment station at Runnymede (post office, Narcoossee), Osceola County, Fla. The crop was grown as food for stock. The field in which the crop was grown is high-pine sand, with almost no other ingredient. The illustration of the cassava given herewith is from a photograph of a plant taken from a field near the station. The soil on which it was grown was apparently pure sand. It represents the larger plants in the field, but not by any means the largest. The illustration (fig. 16) shows in a striking manner the stem and root development. This plant, of which the photograph is given, was 5 feet high. The roots in the soil occupy a more nearly horizontal position than is shown in the figure. The thickened part of the stem, to which the roots are attached, represents the cutting from which the plant grew.

Attempts were also made to grow the cassava in a piece of very wet muck land at the station in which sugar cane would not grow to any advantage. An immense development of tops was secured, some of the plants reaching a height of 10 feet and resembling young trees. The root development was fair, but not commensurately increased with the top growth. Some of the stems were easily 2 inches in diameter. On well-drained muck land I think the crop would be large and profitable.


Fig. 16.—Cassava plant, showing stem and root development.

In sand land the planting should be preceded by the removal of stumps, sprouts, etc., and the soil given a thorough plowing. It is advisable to spread about 300 pounds of fine raw Florida phosphate floats or about 150 pounds of superphosphate containing 12 per cent available acid to the acre. This may be applied as a top-dressing and thoroughly worked into the soil by a deep-running cultivator. The rows should be marked out in furrows 3 to 4 inches deep and from 3½ to 4 feet apart. To get a good stand about double the number of cuttings required to produce 2,500 hills per acre should be planted. The excess of plants can be removed with a hoe as soon as vigorous growth is assured, leaving one hill every 3 or 4 feet. About 150 pounds of kainit per acre should be dropped in the hills before planting, together with an equal amount of cottonseed meal, or half that amount of Chile saltpeter (nitrate of soda).

The cultivation should be such as to keep the field free of all weeds and the surface of the soil well stirred. While the plants are young, deep cultivation is not objectionable, but as soon as the root system begins to develop, superficial culture must be practiced not to exceed 2 inches in depth. Some cultivators draw the soil to the plant during cultivation, so as to form a ridge at the time of laying by. Where nitrate of soda has been used an additional 50 or 75 pounds per acre should be sown broadcast just before the final cultivation.

The above method is the one which should be followed for the poorest kind of sand soils, where a maximum crop is desired. For muck soils, the cotton-seed meal and nitrate of soda should be omitted and about 500 pounds of Florida phosphate floats used per acre. If sand soils are covered with a good layer of muck before the plowing the nitrogenous fertilizers may also be omitted or reduced in quantity.

In ordinary seasons with the treatment outlined above, a crop of from 4 to 7 tons per acre will be secured. On sand soils containing a little organic matter approaching the hammock variety, a fair yield of from 2 to 4 tons per acre will be secured by good cultivation without fertilizing.

For seed, the stems of the unfrosted plants are cut into pieces about 6 inches in length, care being taken that each piece has two or more eyes. In planting, these pieces may be laid directly down in the furrows and covered, but the general practice is to place them obliquely in the furrows so that one end may not be covered. In case of a threatening frost before a field is ready for planting, the unfrosted tops may be cut, thrown into heaps, and protected with leaves or trash from the action of the frost. They should, however, be embedded in moderately moist earth if they are to be kept for any length of time before planting. In case of frost before the seed is saved, the stumps, i. e., the points of union of the top with the root, will usually be found uninjured, and these may be cut away and planted instead of the cuttings just described. The larger parts of the stems immediately above the ground make the best seed.

The roots should be left in the ground until they are needed for use, whether for food, for starch, or for glucose. The crop can be harvested at any time during the year, but the best season is from October to May. The roots should not be allowed to grow more than two seasons, and for most purposes it is believed that an annual harvest will prove the more profitable.

As is the case with all new and promising plants, the most extravagant statements have been made in regard to the amount of cassava which can be produced per acre. In many of the returns received from our correspondents in Florida statements were made in regard to the yield which were entirely beyond the bounds of reason. These extravagant statements, of course, did not proceed from any desire on the part of correspondents to misstate the facts, but on account of their misapprehension of them. Statements of yield are made, as a rule, not upon accurately measured and weighed products, but upon a mere glance over a field or the taking of a few hills. It is easy, therefore, for the most honest and upright correspondent to fall into gross error in regard to the amount which will be furnished by an acre. In my own observation of small areas, and from the accredited statements of those authorities which seem to merit the highest consideration. I am convinced that on the ordinary pine land of Florida, with proper preparation and cultivation and appropriate fertilization, a yield of from 4 to 7 or perhaps 8 tons per acre may be reasonably expected. It is difficult to see, however, how it is possible for such yields as have been reported—viz, 40, 50, and even 60 tons per acre—to be gathered. In exceptional conditions, as is the case with all crops, exceptional yields may be obtained, but these must not be considered in the practical study of the problem of profitable production.

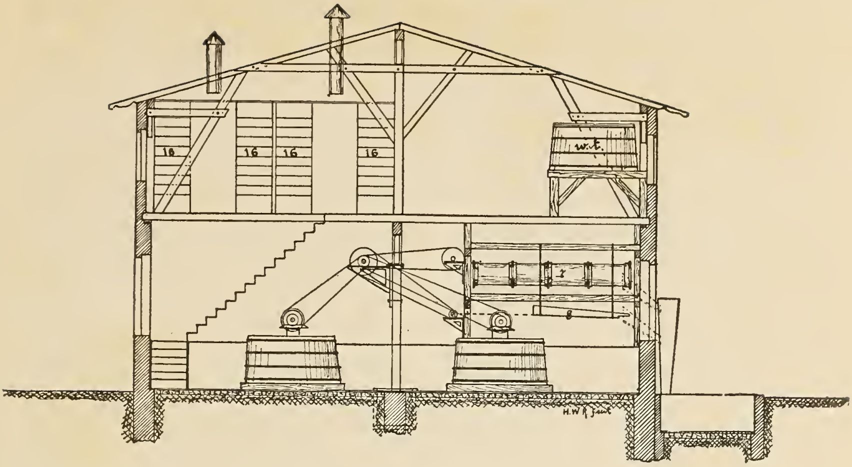
The profit which the farmer may make from growing this crop and the manufacturer from using it should, in my opinion, be based upon a yield of 4 or 5 tons per acre. If it be desired to make starch from the plant, we may suppose as a minimum rate of yield that 20 per cent of the weight of the fresh root may be obtained as merchantable starch of a high grade. On a yield of 4 tons per acre this would amount to eight-tenths of a ton, or 1,600 pounds. Compare this with the weight of starch obtained from indian corn producing 40 bushels per acre. The yield of merchantable starch of a high grade may be placed at 35 pounds per bushel, which for 40 bushels would amount to 1,400 pounds. It is thus seen that the rate of yield per acre in the matter of starch from cassava would be fully equal if not superior to that from indian corn.

If the matter of the manufacture of glucose be considered, the estimate is even more favorable. Our experiments have shown that after the removal of the bark the whole root may be rasped and treated directly for the manufacture of glucose, either by inversion with diastase or by treating with dilute sulphuric acid. In the latter case not only were the starch and sugar present in the root obtained as glucose, but also a considerable quantity of the digestible fiber. It is not an extravagant statement, therefore, to suppose that fully 30 per cent of the weight of the fresh root could be obtained as commercial glucose. This would give a yield per acre of 1.2 tons, or 2,400 pounds. These statements are made, of course, subject to the practical determinations of the manufacturer of glucose and starch from this plant. Attempts have already been made in the manufacture of starch, but of course the full development of this industry must await the investment of capital and the necessary adjustment of new machinery to new processes.

PLANS FOR A STARCH FACTORY USING POTATOES OR CASSAVA.

Through the kindness of Mr. B. Remmers, of De Land, Fla., the plan of a starch factory suited for the working of either cassava or potatoes is presented.

It would be advisable for all factories for this purpose to be built upon some such plan as is shown in the accompanying illustration (fig. 17), since by an arrangement of this kind the greatest economy



Cross section of starch factory.

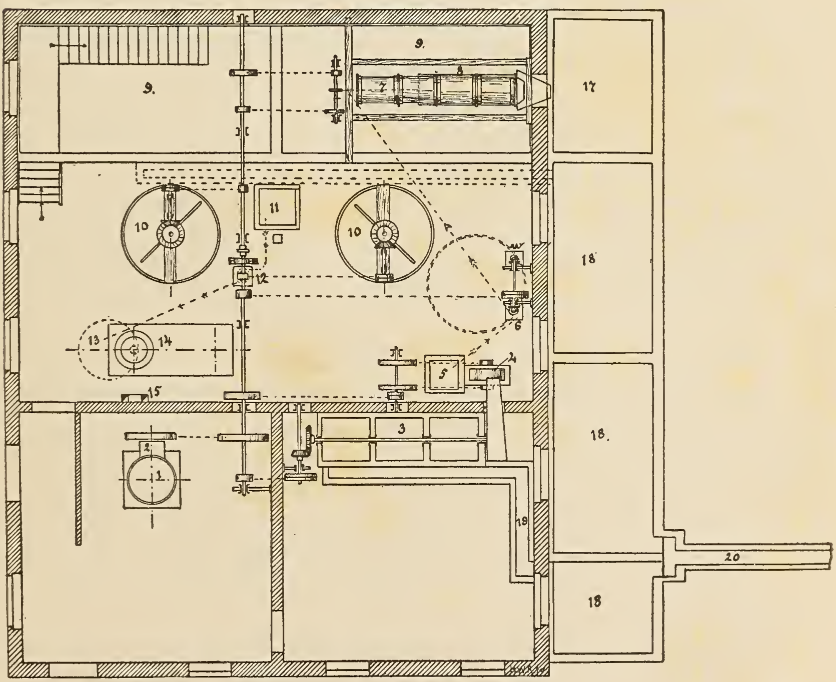


FIG. 17.—Plans for starch factory for Irish potatoes or cassava: 1, boiler; 2, engine; 3, root washer; 4, grater; 5, grater tank; 6, pump from grater tank to sieve; 7, cylinder sieve; 8, shaking sieve; 9, starch settling tanks; 10, stirring tanks; 11, milk tanks; 12, milk pump; 13, centrifugal tank; 14, centrifugal; 15, starch elevator; 16, drying rooms; 17, pulp tank; 18, outside settling tanks; 19, water from washer; 20, overflow to irrigation; (*w*, fresh water pump).

of space is secured and the most convenient method of handling the product can be instituted. In point of fact, however, many of the potato-starch factories have been placed in buildings which were originally intended for other purposes, so that the convenience of arrangement which is shown in the above plan is not always found.

Mr. B. Remmers, of De Land, Fla., who has prepared this plan has made many valuable suggestions in regard to the industry of manufacturing starch from cassava. According to the information which he has given, the general course of procedure in the manufacture of starch from cassava is the same as with potatoes. All the machinery used in the potato-starch factories can be employed just as well in the cassava factories, but the character of the rasps and bolting cloths must be adapted to the changed conditions due to the differences in the raw materials employed. There are many makers of potato-starch apparatus in the United States, and some manufacturers prefer one form of apparatus and some another. The same is true in regard to the working processes: one person prefers the tabling of the starch directly from the grater after sifting, while another prefers the settling tanks, and still others a combination of both.

It is evident that the methods of work must be adapted to the conditions which obtain and the character of the materials to be employed. In some seasons both the cassava and potatoes yield better results than in others, and only large experience can determine in the multitude of details the best method to be pursued.

During the season of 1898–99 Mr. Remmers, with imperfect machinery, secured a yield of 20 per cent of commercial starch on the weight of cassava root employed, and therefore with improved machinery and improved cultivation it will not be difficult to bring this yield up to 25 per cent.

It is evident from a careful study of the problem in so far as it has been worked out in practical experience, and theoretically considered, that very little change in machinery and methods will be found necessary in adapting a starch factory to the preparation of starch from cassava. Since cassava will yield nearly double the percentage of starch obtained from an equal weight of potatoes, it is evident that in this plant the practical man will find a promising source of profit in those sections of our country where the soil and climate are suited to the growth of cassava.

Large areas in Florida are well suited to cassava growing which so far have not been found profitable for other agricultural purposes.

PRESENT STATUS OF THE CASSAVA INDUSTRY IN FLORIDA.

The factory of the Seminole Manufacturing Company, at De Land, began operations in the season of 1898–99. Difficulties developed in the application of machinery selected for the manufacture of starch from cassava. While this factory will be idle during the season of 1899–1900, the officials of the company are confident of the final success of cassava as a commercial source of starch, and propose to continue operations at De Land, or in that vicinity.

The factory of the Planters' Manufacturing Company has been completed at Lake Mary in time for the crop of 1899 and 1900. It appears that when changes are made in the pulping machinery to avoid difficulties arising from the more fibrous nature of the cassava root, as compared with potatoes, the success of the manufacture of cassava starch on a large scale will be assured. The nature of this difficulty is not such that it will long baffle the efforts of our mechanical engineers.

The McIntosh Cassava Company, a cooperative organization, proposes to erect a factory at McIntosh for the crop of 1900–1901.

The interest of the people is thoroughly aroused and the value of cassava as a stock food and as a source of starch is thoroughly appreciated. The agricultural experiment station of Florida has been especially active in conducting investigations in regard to the culture and feeding value of the plant, and in bringing the results of these experiments to the attention of the farmers of the State. A considerable part of the station farm is devoted to the cassava experiments.